MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
VINNYTSIA NATIONAL AGRARIAN UNIVERSITY

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PRODUCTION AND USE OF BIOFUELS

2nd edition, supplemented

Textbook

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This book is intended to serve as a compendium on the state-of-the-art research in the field of biofuels. It aspires to be a comprehensive summary of current biofuels issues and thereby contribute to the understanding of this important topic. Scientific, methodical, organizational and economic principles of production and consumption of biofuels and other alternative energy sources are highlighted in this book. Global trends of biofuels development are generalized considering biomass potential available in Ukraine, environmental sustainability and economic feasibility of biofuels consumption while maintaining food safety of the state and competitiveness on the global market of fuels.

For students, graduate students, teachers, researchers, agriculture specialists, ecologists, power engineers, economists and entrepreneurs.

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Contents

Acronyms, Abbreviations and Units

AES	–	Alternative Energy Sources
B100	–	100% biodiesel
DDGS	–	Dried Distillers Grains with Solubles
FAO	–	Food and Agriculture Organization
GPP	–	Geothermal Power Plant
IEA	–	International Energy Agency
NPP	–	Nuclear Power Plant
RFS	–	Renuable Fuel Standard
S. F.	–	Standard Fuels
SBR	–	Sequencing Battery Reactor
SPE	–	Solar Power Energy
STC	–	Science and Technology Center
STPP	–	Solar Thermal Power Plant
TPP	–	Thermal Power Plant
WTO	–	World Trade Organization

PREFACE

The history of civilization is the process of searching energy sources. Today, it is an urgent task because energy is the possibility of further development of the state, obtaining stable yields, improving the living conditions of people.

The most important source of energy is the Sun (30 % of the solar energy that falls on earth is reflected back into space, 47 % is spent on heating the earth's surface, 22 % – on the water cycle, 0.2 % – for the formation of wind, waves, ocean currents and only 0.8% is absorbed during photosynthesis). Through photosynthesis we have our main form of energy – minerals and biomass. Each year the Earth receives about 3•1024 Joules of solar energy.

If we compare this amount with the volume of energy contained in proven reserves of natural gas, coal, oil, uranium, it becomes clear that in one week the Earth receives from the Sun the same amount of energy as more than double volume of all the known reserves of energy on Earth.

All energy sources can be divided into renewable and non-renewable. Renewable energy sources are characterized by a natural completion in a relatively short period of time. Due to this they have a constant power. Non-renewable energy sources are characterized by their inability to recharge after use.

The whole world is waiting in conditions of serious energy crisis. The basis of the research priorities of most developed countries are finding ways to use renewable energy sources, which is accumulated by plants through photosynthesis. Special attention is given to crops that are able to collect solar energy, biomass waste, waste from livestock processing industry. The combustion of energy is a natural metabolism, and carbon dioxide, which is formed again absorbed by plants. So, in order to preserve natural resources and improve the environmental science proposed closed exchange loop of energy consumption and reproduction, which is biofuel.

Biofuels is a fuel derived from organic matter (directly from plants or from agricultural, domestic and industrial organic waste). Its advantage is the environmental friendliness and the possibility of production from renewable feedstock. Such biofuels as bioethanol, biodiesel, biogas are the most cost effective, and therefore the most promising.

The increasing cost of traditional energy sources, the increasing deficit of energy and the negative environmental impact of fossil fuels consumption are the main driving forces causing the constant growth of biofuels worldwide. For further development of the economy according to international standards bio-energy development is particularly important for Ukraine. At the present stage of development of the state production of biofuels is one of the main catalysts of new global trends in agriculture in Ukraine. This is due to the reduction of mineral resources, high dependence on oil imports, changes in the structure of agricultural production, the continued growth disparity in prices for energy, industrial and agricultural products.

Ukraine has strong natural resource potential for growing biomaterials and should move from export-oriented agriculture to energy crops production with possibility of their processing into biofuels in the country.

The purpose of the textbook – to help to acquire knowledge on alternative energy sources, including the efficient production and use of biofuels made from crops and agricultural production waste to ensure the agro-industrial complex of Ukraine and the entire energy sector with own, clean and high quality energy.

The peculiarity of the textbook is that it covers the entire process chain, from cultivation of agricultural products with desired properties to the final stage of biomaterial processing for different types of biofuels. In studying textbook material, the author expects the existing of students' knowledge of crop production, livestock breeding, agricultural machinery, technology bases of agricultural products processing and production economics.

ABOUT THE AUTHOR

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G. Kaletnik was born on 02 May 1949 in the village of Klembivka in Yampil district Vinnytsia region. He graduated from the Ukrainian Agricultural Academy in 1971 and Ukrainian State University of Food Technologies in 1998. His labor activity began in the Yampil district as the chief engineer of the collective farm. Then he worked as the chief engineer of the regional agricultural department, the manager of the regional association "Silkhosptekhnika", the chairman of the collective enterprise, the chairman of the regional agro-industrial association, the representative of the President of Ukraine in the Yampil region, the general director of the scientific and production association "Elita", the director of the Vinnytsia regional state experimental agricultural station, the general director of the Vinnytsia regional state association of alcohol and liquor industry. In 1998, on an alternative basis, he was elected as a chairman of the Vinnytsia Regional Council. In 2004, he was appointed the chairman of the Vinnytsia Regional State Administration.

G. Kaletnik has been a rector of Vinnytsia State Agrarian University since July 2009. In addition, under his leadership, the university received the status of national. In March 2013, he was elected as the president of Vinnytsia National Agrarian University at a labor collective conference by secret ballot.

Gryhorii Kaletnik is the author of more than 250 scientific, educational and methodical works, including 22 monographs, 19 manuals and 7 textbooks. He has 30 patents for inventions, 2 copyright certificates and 2 copyright works.

As a People's Deputy of Ukraine and Chairman of the Verkhovna Rada Committee on Agrarian Policy and Land Relations, he is the author of more than 70 draft laws, 50 of which were supported at plenary session of the Ukrainian Parliament and came into force as laws dealing with the development of the agricultural sector, land issues, energy, environmental and food safety of the state, education.

CHAPTER 1
GENERAL DESCRIPTION OF ALTERNATIVE ENERGY: DEVELOPMENT, PROBLEMS AND PROSPECTS

Key issues

1.1. The Role of Power Engineering in Economic Development
1.2. The Use of Traditional and Alternative Energy Sources
1.3. The Resource Base of Alternative Energy Sources
1.4. The Potential of Alternative Energy Sources in Ukraine
1.5. The History of World Bioenergy Development
1.6. Socio and Economic Need and Importance of the Biofuels Market in Ukraine

1.1 The Role of Power Engineering in Economic Development

Power engineering is a network of interconnected components which convert different forms of energy into electrical energy. In another words, it is a set of industries that deals with the generation, transmission, distribution and utilization of energy as well as the design of a range of related devices.

The level of development of energy sector of any country has a decisive impact on its economy, the economic growth rate, the state of the environment, solving social problems and living standards. So, reasonably energy security and independence is always associated with national security.

Energy security is the component of economic security, focused on the impact of management subject on threats and dangers, creation necessary and sufficient conditions by governmental and nongovernmental institutions in order to prevent deficiency in providing consumers with fuel of affordable cost and energy resources of acceptable quality in normal and emergency conditions, the consistent and active policy of energy conservation and diversification of energy sources, ensuring effective operation of the energy security subsystem.

Energy demand is determined by three main factors: population growth, economic development of the society and the scientific and technological level of production processes performance. Of course, the demand in energy grows in the world from year to year, and in 2014 it exceeded 10 billion tons.

Oil, natural gas and coal are the main energy resources of the world economy. Stable functioning of fossil fuel markets, ensuring its constant supply to consumers is an issue of national security.

The relationship between consumers and producers of fossil fuels is an important factor in the modern world and fluctuations in oil prices are able to cause political instability in the country.

Along with the increase in world population and energy production, respectively, energy production is continuously increasing. In the last 100 years, world population has increased almost in four times, and the annual extraction of energy resources – in 21 times. Today, one inhabitant of the planet has 2.5 tons of s.f. According to preliminary estimates, the population will grow to 10 billion people till 2100, and the average specific energy per person – up to 10 tons of s.f. Generally energy production will reach 100 billion tons of s.f (virtually all fossil fuels, especially oil and gas, can be exhausted).

Solar radiation brings annually to our planet 0,7 · 1,018 kilowatt-hours of energy, which is equivalent to 84 trillion tons of s.f., or 3 · 1024 Joules. Flowing solar energy is transformed into heat energy land and ocean energy currents, waves, wind, chemical, geothermal and biological energy, and after all kinds of transformations radiated back into space mainly in the form of low-temperature infrared radiation.

According to the controversial estimates and forecasts of the impact of mankind on global climate processes, researchers were able to convince the governments of 186 countries that participated in the Congress in Rio de Janeiro (1992) in the need to take urgent coordinated measures in order to reduce emissions of gases. Further targeted research and the processes taking place in the world, have led to greater understanding on the need for consistent implementation of both domestic and international measures to reduce human impact on the atmosphere.

It has been obtained the generalized, undeniable conclusions that global electricity sector is responsible for a third of released gases, and for the period up to 2020 will be responsible for the annual increase in gas emissions by 2.5%. Previously predicted that the OECD has until 2010 Kyoto Protocol set emission levels may increase, the annual contribution of developing countries can reach 3.5-4.1%, and by 2020 – almost 30% of the global CO_2 emissions.

So, increasing understanding of the need to harmonize policies to balance shifting toward fundamental obligations relating to the properties of the environment and energy security should be approved. The importance of compliance with environmental safety also discussed at the climate conference in Copenhagen in December 2009, which was attended by 192 countries, leading environmental and social organizations. Following the conference, the participants signed an declarative agreement, and making full agreement on climate was postponed until 2010. The French President said that, according to the document, all states should confirm in writing plans to reduce emissions of carbon dioxide. Developing countries annually will receive financial assistance of up to $ 100 billion till 2020.

Consumption structure and trends in the global energy sector. Prospects for energy on a global scale weregeneralized by International Institute for Applied Systems Analysis (IIASA) in conjunction with the World Energy Council (WEC). Based on the results of studies, the trends of power engineering in the XXI century has been identified:

1. Benefits will be given to high-quality fuels and efficient use of extensive infrastructure (oil and gas pipelines, and powerful local grid).
2. The infrastructure will remain the basis of the energy system and the need for its expansion grow.
3. The benefits in technological complex will be given to those that are equipped with the flexible mechanisms of development.
4. The use of oil and gas will decrease with increasing the share of renewable energy.
5. Production of synthetic fuels, natural gas and in the future hydrogen from natural gas, coal and biomass will become the most important on the market of new technologies.
6. Will increase the role of decentralized energy technologies of local importance, especially in urban areas with agricultural development.

7. Further overregulation and liberalization of electricity markets will be implemented and focused on consumption and supply of energy from renewable sources.

Annually Ukraine consumes about 200 million tons of s.f. fuel and energy resources (FER) and belongs to energy deficit countries as cover its needs for energy consumption by about 53% and imports by 75% of the required amount of natural gas and 85% crude oil and petroleum products. This FER structure is economically unfeasible, generates dependence of Ukraine from oil and gas exporting countries. This situation is threatening its energy and national security.

The structure of energy supply in Ukraine has the highest proportion of coal (34.54%),natural gas (29.84%), nuclear (22.51%) and fuel oil (10.38%). Currently, the share of renewable energy in Ukraine accounted for only 2.72% (Fig. 1.1).

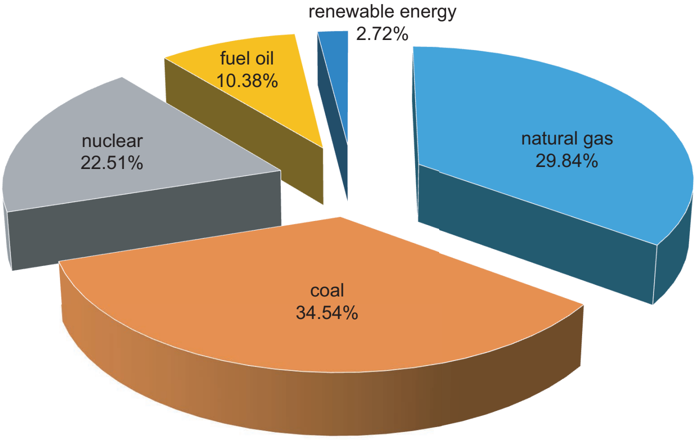


Figure 1.1. Structure of total primary energy supply in Ukraine in 2017

The limited domestic energy resources, dependence on fossil fuels imports and constantly rising prices predetermine the need of transition an immediate transition to the use of alternative fuels, considering the fact that Ukraine has the resource potential for their. Previously Ukraine only had to solve the problem of high cost of imported natural gas, now generally called into question is the possibility and conditions of its imports. Difficulties also started to arise with the supply of coal.

Socio-economic necessity of providing Ukraine with energy produces in the country puts the problem of finding alternative fuels. However, environmental damage from vehicles emissions that run on gasoline and diesel fuel becomes more tangible.

As for the study of economic and social necessity of formation and development of the biofuel market in Ukraine, it should take into account several factors, starting from reasons of energy security, diversification of national production, support of innovations and ending with economic and social efficiency of the biofuel market through high motivation for sustainable development of the agricultural sector, positive social changes on the growth of rural employment and environmental safety.

The problem of renewable energy has strategic importance for economic development of Ukraine in general and agriculture in particular, due to such objective factors as: ensuring energy security and reduction dependence on energy imports; development and stability of the agricultural sector of the country; the creation of new jobs and increase in revenue; improving the environmental situation.

In the present situation there is no alternative to the successful implementation of the program of production of biofuels.

Ensuring stable energy economy is the main problem to be solved and economic growth of Ukraine depends on the results.

Ukraine exports most of agricultural products as a raw material. Instead it is more reasonable to convert it into fuel and energy components as there is no alternative way of further development. Ukraine cannot remain aloof in creating bioenergy technologies for biofuel production because it will mean insecurity and low competitiveness of the economy on international markets.

Considering the difficulties in the unattractive energy sector and environmental situation, Ukraine should immediately begin widespread introduction of bioenergy technologies with the use of all biofuels: solid, liquid, gaseous. The development of biofuel production and use must take place in order to ensure the energy, environmental, economic and food security of the state.

1.2 The Use of Traditional and Alternative Energy Sources

Wood energy, potential energy of water in dams, the kinetic energy of the wind and the radiant energy of sunlight have been the main types of energy used by human for thousands of years.

Since the beginning of the 21th century, in a period of rapid development of technology, the main energy sources were natural resources: coal, oil, natural gas and energy of big rivers, which now belongs to traditional energy sources. In addition, later they began to attribute the power of the atom.

Traditional energy sources converted into heat or electrical energy by using special plants – power plants, hydroelectric power or nuclear power plants. The coefficient of performance (COP) of traditional energy sources conversion on such stations is low (ten percent).

Reserves of fossil fuels. Reserves of fossil fuels in the world are estimated as follows (in billion tons of s.f.): coal – 727; oil – 196; gas – 144; total – 6300.

There are other estimates of world reserves of primary energy resources. At the level of global coal production – 3.1-3.3 billion tons of s.f .; oil – 4.1-4.3 billion tons of s.f.; gas – 0.9-1.3 billion tons of s.f. This coal reserves will last for 240 years, oil – for 50 years and gas – for 150 years.

The largest oil reserves (in billions of m^3) were concentrated in the following countries: Saudi Arabia (41.2), Canada (28.6), Iraq (18.0), Kuwait (14.9) United Arab Emirates (14.7), Iran (14.2), Venezuela (12.3), Russia (9.5), Libya (4.7), Nigeria (3.8). Kazakhstan oil reserves are estimated at 1.4 billion m^3, Azerbaijan – 1.1 billion m^3.

According to natural gas reserves, primacy belongs to the Russian Federation, where of 47.6 trln m^3 or 30.5% of world reserves has been concentrated. Lower reserves (in trillion of m^3) conbe found in the following countries: Iran (23.0), Qatar (14.4), Saudi Arabia (6.3), United Arab Emirates (5.6), USA (5.2), Algeria (4.5), Venezuela (4.0), Nigeria (3.4), Iraq (3.1). Among the countries of the Cas-pian the gas reserves are concentrated in Turkmenistan – 2.0 trillion m^3, Uzbeki-stan – 1.9 trillion m^3, Kazakhstan – 1.8 trillion m^3, Azerbaijan – 0,85 trillion m^3. In the European Union's the biggest gas reserves are concentrated in Norway (2.2 trillion m^3), Netherlands (1.8 trillion m^3) and the UK (1.3 trillion m^3).

The economic potential of hydropower in the world is 8.1 trillion kWh, the installed capacity of all hydro – 669 000 MW, the amount of electricity produced by them today – 2.691 trillion kWh. According to the economic potential of small and micro-hydro it is approximately 10% of the total economic potential. For example, in Russia there is 600 billion kWh, 43 940 MW, 157.5 billion kWh respectively.

The two main disadvantages of the use of traditional energy sources are the following:

1. Traditional resources are not renewable hence the term of their use is limited, that is why there is a need to find new methods of energy production.

2. The use of traditional resources for energy efficiency leads to significant environmental effects – environmental pollution.

One of the urgent problems on our planet is the increasing the concentration of carbon dioxide and global warming that is caused by number of increased mining and processing of carbohydrates. Over the last century, annual oil production increased by 20 times and the world is in terms of the expected planetary energy crisis. According to this rate of hydrocarbons consumption and estimates of international experts, almost all fossil fuel reserves can be depleted in the next 40 years.

It is becoming increasingly clear that it is necessary to limit the use of fossil fuels to the level at which the global environment can handle emissions. The focus in the future should not be given to the stocks of fuel reserves but to the amount of fuel which can be used without serious damages of ecosystems that affect on our well-being.

The scientists calculated that in order to limit climate change to a safe level at which we can avoid possible danger to the existence of ecosystems in the 21th century, we can use only a quarter of the amount of fossil fuel that is considered to be cost-effective to use now. Thus, the focus in the short term should not be given to the increase production volumes of fossil fuels but to the definition of its quantity that can be used without serious violations for ecosystems. The well-being of the planet depends on this. Also, according to the scientists' calculations, limiting climate change and keeping it at a safe level, which could prevent danger to the existence of ecosystems in the 21th century is possible only by use of a quarter of the amount of fossil fuel, which is now considered economically viable for consumption.

Energy production from renewable sources, including biomass is developing dynamically in most European countries. The EU has a target of 20% renewable energy in 2020. In 2014, 16% was reached and thus, it has been concluded that the EU is well on its way to achieve the target. After all, thousands of wind turbines are being built in our countryside and millions of solar panels are being installed on our rooftops.

Among the renewable energy sources the most important source in the EU countries was biomass share in the structure of renewables that accounted for almost one-third (65.5%). Hydropower was the second major source of renewable energy, reaching 16.2% of the total. Although the level of production of wind and solar energy is relatively low, their share had 10.0 and 5.1% respectively of the output of renewable energy in 2012. Share of geothermal energy accounted for 3.2%, the energy of tides, waves and ocean energy gained only 0.02% and was used only in France and the UK.

Scandinavian countries are Europe's leaders when it comes to renewable energy, with Sweden and Norway performing the best. Significant differences in the share of renewable energy in the energy balance of the Member States is largely due to supply of natural resources and climatic conditions. For example, 62.5% of renewable energy produced in Cyprus is obtained by solar energy, while more than a third of renewable energy in relatively mountainous countries such as Austria, Slovenia and Croatia is provided hydropower. More than a quarter (27.7%) of enewable energy production in Italy was received from geothermal energy (where there are active volcanic processes). The share of wind energy is quite high in Ireland (46.3%) and in Portugal, the UK, Denmark and Spain. However, none of the developed countries have not declared any plans to reduce the production of energy from biomass. On the contrary, national energy program of the EU countries, USA and Canada are planning further expansion of the sector.

Climate change, acid rain, radioactive waste, oil spills and transport emissions endanger human health, economy and environment. All this is the result of inefficient energy use and negligent attitude to the environment from each of us and humanity in general. Global processes in the modern world forced to rethink and evaluate many phenomena of socio-economic and especially environmental character, tie them in a continuous stream of continuous change and transformation, seek new mechanisms that are adequate to time requirements of managing these processes, new alternative energy sources.

Ukrainian scientists have noted that our country, like many others, suffer from a climate change. Ukraine is threatened by abnormal temperature conditions, the conversion of the southern region steppe into desert, flooding coast-al areas of the Black and Azov Seas, an acute shortage of drinking water in the southern and eastern regions. It threatens the economic development of Ukraine in subsequent decades. It is the economic, environmental and social consequences of forcing governments to implement new environmental policy, including the policy of reducing greenhouse gas emissions.

For greenhouse gas emissions Ukraine is among the twenty largest polluters of the planet, but the solution to this problem is given insufficient attention.

The main obligations of Ukraine under the UN Framework Convention and the Kyoto Protocol is proceeding in accordance with the policy of reducing gas emissions by all sectors of the economy and the formation of the relevant legislation. This work involves a review of existing strategies in Ukraine in energy, transport, industry, agriculture and housing in a way that further development of the national economy was accompanied by a decrease in negative impact on the climate.

Reducing greenhouse gas emissions is not only necessary but also desirable and possible in the practical implementation of effective low-cost programs in all countries. Many of these strategies and programs developed in accordance with the objectives of extended environmentally sustainable development, improving of environmental safety, reducing local pollution, fighting poverty, improving conservation practices and land use. It is in the interest of every country to develop activities that will significantly reduce greenhouse gas emissions.

The basic principles of anthropogenic emissions reduction and increasing absorption of greenhouse gases are:

– to minimize adverse social, environmental and economic consequences of anthropogenic emissions of gases;

– creating enabling environments for business in the implementation of eco-efficient technologies and achievements aimeded to reduce the anthropogenic emissions and increase absorption of greenhouse gases;

– state regulation of business entities in terms of anthropogenic emissions shortage and increasing absorption of greenhouse gases;

– scientific substantiation, systematic and competent approach to the reduction of anthropogenic emissions and increasing absorption of greenhouse gases;

– formation and implementation in accordance with national conditions and public policy measures set out in Article 2 of the Kyoto Protocol;

– regulation of emissions of greenhouse gases, taking into account economic feasibility, level of technological processes, technical condition of equipment and facilities, combined with market mechanisms of reducing greenhouse gases and increasing their acquisitions aimed at ensuring economic growth and stimulate the use of new technologies and innovation;

– the use of market relations and competition as one of the main instruments to stimulate environmental performance;

– stimulating the development of energy industry based on bioenergy, transport, utilities, resource-saving production, housing and related services sector, improving the environment in Ukraine and quality of life;

– ensuring the economic attractiveness of investments to improve environmental performance and reduce greenhouse gases emissions.

Providing the energy efficiency of economy and use of renewable energy will play a vital role in Ukraine towards environmentally sustainable energy infrastructures. The share in the energy sector of fossil fuels will decline, and the necessary changes for the benefit of highly efficient technologies and fuels with less carbon per unit of energy will take place. Alternative energy opens better opportunities for providing jobs to the population.

The integration of our country into a single global space is more and more understanding in the scientific community and in society as economic, social, technological, ecological and biological processes in the human environment are so closely intertwined that there is an objective need to analyze their relationship functioning as a complex socio-ecological-economic system, and more specifically, between modern production and nature.

Organization of biofuels production is a promising direction towards the reduction of Ukraine's energy dependence on suppliers of oil and natural gas. The use of biofuels reduces anthropogenic pressure on the environment, preserves natural resources by recycling renewable agricultural raw materials and waste processing industries of agriculture. On fig. 1.2 we can see the reasons for production of biofuels and their main advantages.

Biofuels	
reasons for production	***advantages***
Shortage of natural energy sources	Formation of energy independence of the state
Large amounts of CO_2 emissions	New jobs
Increasing energy prices	Stimulating of agricultural production
Destabilization of agriculture and industial complex	Loading capacity of sugar-beet and alcohol industries
States' dependence on energy suppliers	Reducing harmful emissions
Low level of energy security	Ensuring sustainability of agriculture production
Availability of fertile land	Increased revenue of all budgets levels

Figure 1.2. The advantages of biofuels production

Ukraine has a powerful potential of energy sector, while some sub-sectors has to excess capacity that is likely to exceed the needs of state (power from cultivation of agricultural raw materials, oil and gas companies, electricity, sugar and distilleries). In recent years nuclear power worked steadily enough together with pipeline transportation of oil and gas, mining and processing of coal.

At the same time, focus solely on domestic fuel and energy resources has led to a critical level of technological and equipment wear in the sector of enterprises. As a result, today 96% of thermal power equipment already exhausted their resources, and 73% – exceeded the limit. Of the 36 million kW thermal power plants can carry the load only 17 million kilowatts, while others require urgent repairs.

The environment in Ukraine characterize the performance of total emissions in the atmosphere, which in recent years are slightly decreased (table 1.1).

Table 1.1

Air Emissions of Maine Pollutants

Indicator	Years					
	2010	2011	2012	2013	2014	2015
Sulfur dioxide	1222.2	1349.9	1416.2	1406.5	1160.6	854.0
Nitrogen dioxide	587.7	617.9	619.2	618.2	541.4	453.0
Carbon monoxide	2848.3	2813.5	2729.8	2682.5	2283.4	1971.9
Non-methane volatile organic compounds	342.6	335.7	322.4	309.5	270.1	225.8

Using oil as a source of energy is of great environmental hazard to public health. When using mineral fuels, together with such exhaust gases as nitrogen oxide, sulfur oxide, compounds containing lead and soot are entering the air. Carbon monoxide entering the body, reduces the concentration of oxygen in the blood, which is dangerous for people with cardiovascular disease. Carbon dioxide is the main component of greenhouse gas emissions and the excessive amount of this gas in the atmosphere causes the greenhouse effect and global average temperature increase on the planet.

As a result of intensive exploitation of the gas transportation system, the significant part of main gas pipelines, compressors and other equipment are in need of immediate reconstruction; 60% of gas pumping units have already exhausted their resources, and 75% do not meet environmental standards, resulting in use of transmission system needs (as fuel) used more than 6% of transported gas. Without appropriate investment in fixed assets of the energy sector doomed to gradual degradation of output as a technical resource installed equipment.

Two-thirds of the total air pollution in Ukraine accounts for emissions from stationary sources, one third – from road, rail, water and air transport. In Ukraine, we have the biggest energy-intensive segment of the industry of the former Soviet Union. This, as well as a significant proportion of thermal power plants in the electricity structure (over 40%) led to the fact that in Ukraine the atmosphere gets a significant number of harmful substances for human health. In addition, Ukraine is a European "leader" in the volume of greenhouse gases emitted into the atmosphere.

On the other hand, Ukraine has ratified the Kyoto Protocol on climate change, according to which during 2008-2012 it has been allowed to have greenhouse gas emissions on same level as in 1990. Today, when industrial production of the state is experiencing the consequences of the crisis, Ukraine has a certain reserve of quotas for greenhouse gas emissions, which makes it possible to eventually receive significant funds from the sale of quotas. But in the process of industrial recovery energy consumption will significantly increase together with the amount of greenhouse gases. This will lead to a gradual reduction of income funds needed in our country, and eventually require costs to buy corresponding quotas. Considering the problems in areas of traditional Ukrainian power generation, renewable energy prospects look quite attractive.

The first factor that forced the global economy begin the reassessment of energy policy was the understanding of the collision in real term, the problem of exhausting reserves of fossil fuels, which will directly determine changes in value, the cost of production and overall energy security and touches political commonwealth countries. Started revaluation provision their own resources available to engage in the sphere of consumption.

Scientists consider it critical if the temperature on Earth increase (by 3.5°C), what can cause irreversible environmental consequences. This is the limit-ing factor that limits the number of industrial facilities that dump excess heat into the environment. The use of fossil fuels in the transport sector leads to a significant increase in emissions that affect the environment. Experts estimate the combustion of 1 ton of diesel oil released into the atmosphere over 80 kg of pollutants. Solving environmental problems today is very important, dif-ficult and an expensive task, which large companies that cause these problems almost do not pay attention. Use of AES has in this sense indisputable advan-tages because their use hardly leads to negative environmental impacts.

Some environmental impacts from the operation of plants that use alternative sources of energy, of course, exists, but it is minimized with proper organization and safety, compliance with technological standards when working with harmful substances.

As known, alternative energy sources include solar, wind, seas and oceans, geothermal heat, biomass, small rivers and secondary resources that permanently or periodically occur in the environment. Also indisputable advantage of AES is that their potential is constantly renewed, and therefore, useful life is unlimited. Therefore, the National Energy Program of developed countries focuses on the use of renewable (alternative) energy sources.

According to optimistic forecasts of world energy development by 2050, taking into account energy saving, world energy consumption will be about 21.5 billion tons. Of s.f., the share of renewable energy will reach 40%. In different countries, the share of the potential application of ARES in the energy sector today is: Iceland – 64.5%, Norway – 47.8, New Zealand – 32.3, Sweden – 25, Austria – 22 Finland – 20.9, Switzerland – 17.3, Canada – 16.6, Greece – 16.5, Mexico – 11.4, Portugal – 9.8, of Denmark – 7.2 France – 6.8, Australia – 6.3 Spain – 5.4 US – 5 3, Italy – 4.3, Greece – 4.2, Japan – 3.5, Hungary – 3.1, Ireland – 1,9, Luxembourg – 1,6 and Germany – 1,5, Czech Republic – 1.5, Belgium – 1.1 UK – 0.7%. Alternative liquid and gaseous fuels range from 20 to 50% of ARES in different countries. Forecast of increasing amounts of using AES until 2050 has shown in Fig. 1.3.

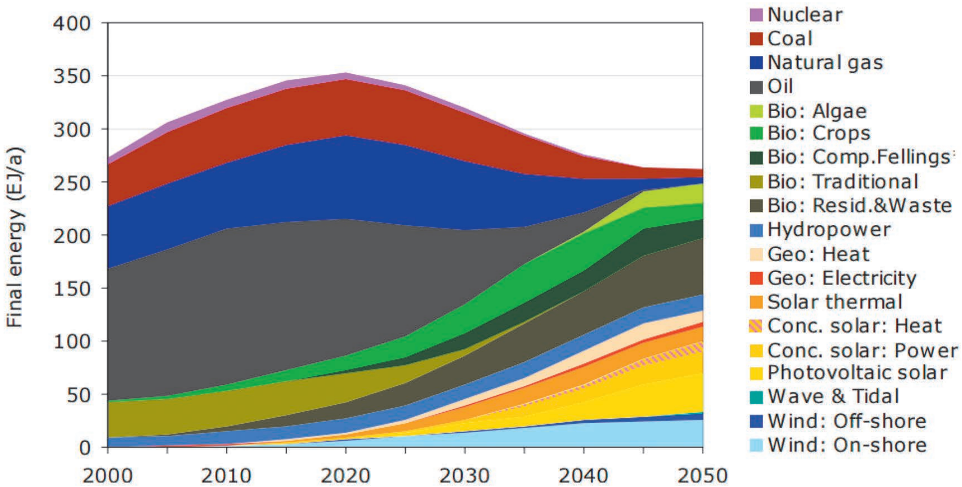


Figure 1.3. Chart Increase in the Use of Alternative Energy Sources to 2050

Benefits of alternative energy are not in doubt: they are virtually inexhaustible sources of energy have almost no impact on the environment, do not re-quire additional processing and transportation.

Despite the advantages of using alternative energy sources, they have some shortcomings that currently limit their widespread use. The main drawback of alternative energy is small energy flow density – there is a need for large surfaces for processing alternative energy sources, and thus, large structures stations. Energy of alternative energy is dispersed and share that is available for human use at the present level of technology is not sufficient to ensure all people's needs in the general scale.

For example, to generate equal amounts of solar power energy (SPE) compared with conventional thermal power plant (TPP), the size of SPE should be 300 times larger than the size of thermal power plants, and for the production of the same amount of energy by wind power should be 2,500 times bigger than the area of nuclear power plant (NPP).

Another drawback of alternative energy sources is considerable unevenness of energy production depending on time of day and the seasons, which requires the use of complex and costly energy storage capacity duplication systems or by traditional energy resources.

Uneven allocation of alternative energy sources and limiting their use – can be used only in the most favorable areas for concentration.

High capital intensity of energy installations and structures even at very favorable operating characteristics of sources and effective way to use it is now the major drawback that limits the widespread use of power plants based on alternative energy sources in Ukraine.

1.3. The Resource Base of Alternative Energy Sources

The emergence of traditional and alternative energy sources objectively linked to centuries and continuous exposure to the sun as the main source of energy on Earth. Earth energy system consists of two parts: the dynamic flow of solar energy and static energy reserve which is the planet itself, that reserves of fossil fuels, nuclear and geothermal alternative energy.

Due to activity of the Sun, we have such traditional energy sources as mineral resources (coal, peat, oil).

In order to assess the energy potential of alternative energy sources that can be used by human accurately, it is divided into three types: general, technical and economically viable.

Overall potential (theoretical potential) is the total amount of energy as characteristic of each energy source.

Technical potential or potential energy resource is the part of energy of overall capacity, which can be implemented using modern technical means.

The economically viable potential is the amount of energy that should be used with taking into account the economic, environmental, technical, technological and political factors.

The total annual potential of alternative energy sources (AES) exceeds the potential reserves of traditional energy sources in 15 times. At the same time, it exceeds the potential of explored reserves of traditional energy sources in 80 times. The technical potential is slightly higher than the current level of energy consumption. And expedient economic potential may be higher than the current level by 40-45%. This shows the great potential of AES that can be developed soon.

According to the degree of AES development, they can be divided into four groups:

1. Energy sources, exploited on a large scale. Such AES have stable technical and economic indicators. These include hydropower and biomass (primarily wood fuel). Prospects for the wider use of hydropower linked only to increasing their technical and economic indicators. Prospects for widespread use of biomass waste have organic agriculture, industry and public utilities sector. Direct use of wood as fuel must be limited. Processing of starch-sugar and oil-containing biomass to liquid fuels is stable and promising.

2. Small-scale mastered energy sources. Their technical and economic parameters depend on specific conditions. These AES include geothermal energy (hot water and steam mixture) and wind power.

3. Energy sources that are under development and have great prospects if their technical and economic performance will be significantly improved – solar energy, organic waste (anaerobic digestion), low-potential heat (use with heat pumps).

4. Energy sources that are under hypothetical development. Assessment of the effectiveness of these type of sources has not been proved – the energy of the ocean in all its forms, dry heat terrestrial rocks and so on. For technical and economic evaluation of the widespread use of AES currently there is not enough theoretical data.

Solar radiant energy. Solar energy is the most powerful source of energy on our planet. The power of solar radiation that falls on 1m^2 of the earth's surface is about 1 kW, and if a surface area is about 100x100 km the power will be about 10 billion kWh.

Solar energy can be converted into heat and electricity. Solar energy can be used to power buildings, heating, water heating and air conditioning, power satellites, the establishment of special solar ovens, which reaches temperatures of 3000°C.

Although the share of solar energy in the world is no more than 1%, the renewable energy industry is developing very quickly. In 2000 the annual worldwide capacity of photovoltaic cells (direct conversion of solar energy into electricity) was 200 MW, and in 2012 it exceeded 100,000 MW.

The leading countries in the area of solar energy are Germany (35.5 GW), China (18.3 GW), Italy (17.6 GW), Japan (13.6 GW), USA (12 GW), Spain (5, 6 GW) and France (4.6 GW).

Now we are observing the fastest rate of developing of using the solar enerergy in China, generally by installing individual solar cells on the roofs of pri-vate houses.

Wind energy. Potential reserves of wind energy in the world is approximately in 2.7 times larger than the total cost of energy on the planet. However, according to estimates, only 5% of this energy can be used. Wind energy is used by people since ancient times – sailing ships, windmills and more.

In most cases, wind energy is converted into electrical energy to power some small objects (some mills) or large objects – a powerful wind power plants (WPP).

The installed capacity of wind turbines in the world increased from 6172 MW in 1996 to 12,000 in 1999, to 36,000 MW in 2006, in 2013 – 318 105 MW. Overall, 103 countries are using wind power on a commercial scale. The electricity generated by wind turbines equals to 4% of the world's electricity consumption in 2013. In global terms, the production of electricity from wind energy in 2013 increased more than in 25 times compared to 2000.

In 2013, World Wind Energy Assosiation identified the list of leading countries in the field of wind energy.

China leading the wind energy market by a large margin in comparison with other countries. In 2013 wind installations produced about 67.7 GW in the country. The current power confidently approaching to 80 GW. Large-scale development of the industry began less than 10 years ago. Since then, China has become the leading country in the global wind energy industry. Wind energy is more necessary than traditional sources that will be insufficient to meet all the energy needs.

The second place in the field of wind energy has been occupied by the USA with a total capacity of 60 GW. The European market leader in wind energy with over 30 GW of capacity is Germany.

As for the largest share of wind energy in the total energy consumption in the country, the world leaders are Denmark (34%), Spain (21%), Portugal (20%), Ireland (16%) and Germany (9%).

The energy of sea waves, tides and ebb. To accumulate this type of energy are used vertical rises and falls of water, horizontal movement of the waves, the concentration of convergent waves in place so that the water pressure could rotate the turbine. The energy of the tides is caused by the influence of the Sun and Moon, in some places the lifting height of water reaches 7-13 meters, and sometimes even 15 m. The energy of sea waves, tides and ebb concentrated on the coasts of the CIS countries, France and China.

Ocean heat energy. Ocean thermal energy can be converted into mechanical work, if there is a source of necessary thermal levels. The temperature of the heated by the sun upper layers of the ocean (sea) can reach 26-30°C, at a depth of several hundred meters the water temperature is 4-7°C. The temperature gradient can reach 26°C. As a result, we can create a new type of power plant – termal gradient that based on solar energy that has been accumulated by waters of seas and oceans The first one was created in Cuba in 1930.

The energy of ocean currents. In the ocean, there is constant moving of huge masses of water: Gulfstream, wind flow, backflow and so on. These "rivers in the ocean" sometimes have many thousands of kilometers long with a width of tens, and sometimes hundreds of kilometers and a depth of 300-500 m. Energy of currents is enormous: when you move 1 million m^3 of water at a speed of 1 m/s, it is equivalent to 10 000 MW. Most currents have continuous mode, regardless of the weather, time of day or season, making them suitable for the production of useful energy.

The energy of salinity gradient. Getting power in this cases is based on the phenomenon of osmosis. Some types of natural and artificial thin walls (membranes) separating the salt and water solution, have the ability willfully "miss" in the direction of clean water solution. Quantitatively, this phenomenon is characterized by osmotic pressure of the solution, creating the potential between salt and fresh water. "Osmotic power" freshwater runoff in the oceans is approximately 2.6 billion kWh.

Geothermal energy. Geothermal energy is practically inexhaustible source of energy for humans. Geothermal energy literally means that heat is the energy of the Earth ("geo" – land, "thermal" – heat). The main source of energy is a constant flow of heat from the heated mineral resources that are focused to the ground. The crust gets heat through friction core, the radioactive decay of elements (like uranium and thorium) and chemical reactions.

For getting the heat that has been accumulated in the ground, first of all it must be raised to the surface. For this people drill the holes, and if the water is hot enough, it rises to the surface naturally, besides we can use pumps if the temperature is lower. Geothermal water is an environmentally clean source of energy that is constantly renewed. It differs significantly from other alternative energy sources that can be used regardless of climatic conditions and seasons.

Geothermal resources of Ukraine are primarily thermal water and heat of warmed dry rocks. In addition, one of the most promising for use in industrial scale can be the hot underground water resources, which are derived from oil and gas wells operating oil and gas fields. The most common source of geothermal energy is the heated water (steam) from the bowels of the earth's crust. Today hot water is used widely for heating houses and water in several countries: Iceland, Australia, New Zealand and Italy. Today in the world there are about 20 geothermal power plants, and their total capacity is about 1.5 GW.

The installed capacity of geothermal power plants (GPP) increased from 700 MW in 1980 to 12,000 MW in 2014. Currently 70 countries have installed geothermal power plants. The leading countries in geothermal energy are the following: the USA – 3389 MW, the Philippines – 2000 MW, Indonesia – 1333 MW, Mexico – 980 MW, Italy – 901 MW, New Zealand – 898 MW. In Iceland, 85% of homes are heated using geothermal energy.

Over the past 30 years GPP's capacity increased by 17 times all over the world. Geothermal energy is rapidly used began from the 2000s.

Bioenergy. Bioenergy is a branch of energetics that is based on the production and use of biomass formed by photosynthesis.

Biomass is a set of animate and inanimate, vegetable and animal matter on our planet.

The main source of bioenergy is green plants which, due to photosynthesis can efficiently convert solar energy to energy needed for people (Fig. 1.4).

An important task is to preserve and enrich the diversity of power plants and to optimize the production process through the introduction and use of modern biotechnology, selective and genetic basis construction of new power plants and improve existing plants to create forms of production with desired parameters.

Today biomass covers on average 15% of primary energy consumption in the world. The share of total domestic biomass energy consumption in the EU is about 10%. However, in some countries, such as Sweden, Brazil, Finland, it is under 32, 25 and 23% of total primary energy consumption respectively.

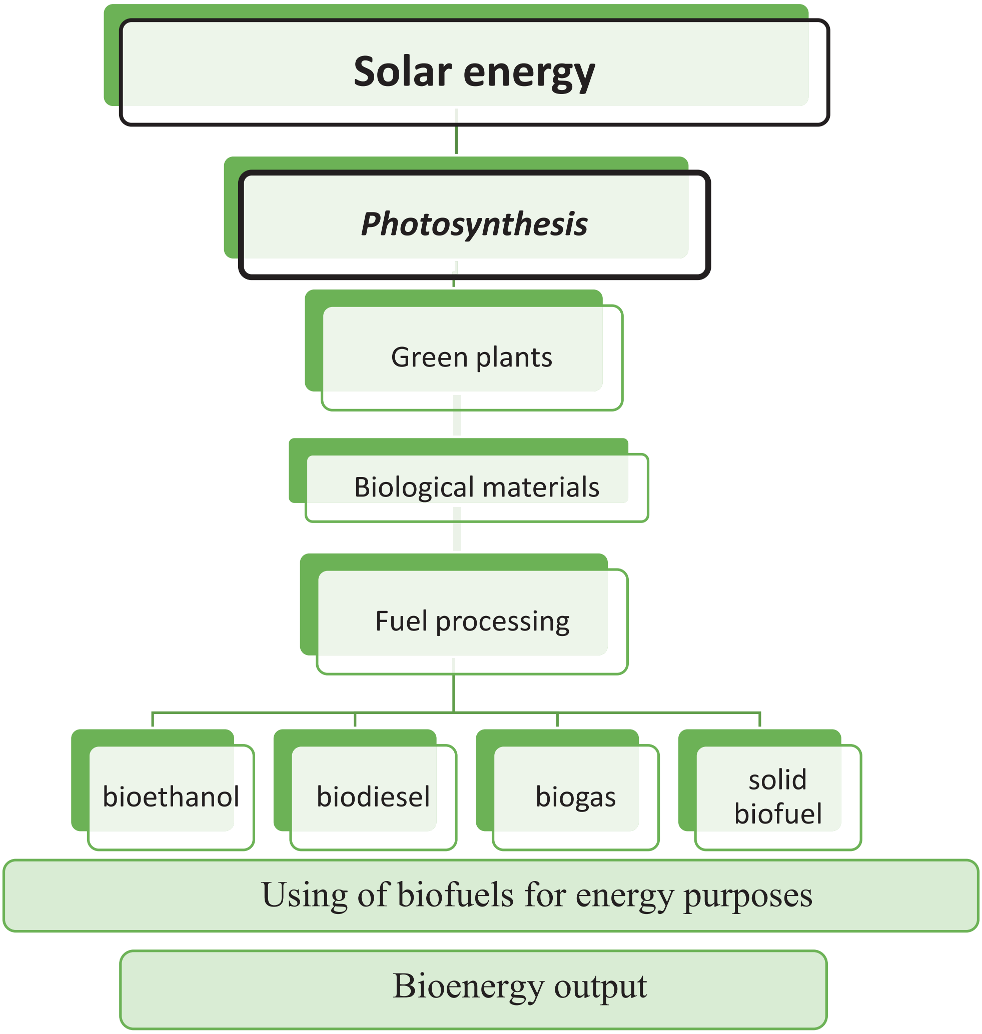


Figure 1.4. Bioenergy Conversion Scheme – Conversion of Solar Energy in Bioenergy Through Green Plants

Biomass is a widespread raw material for energy and includes woody biomass and waste wood processing industry, industrial crops, agricultural residues and agro-industrial effluents, organic part of municipal waste, household waste and sewage.

The EU offers to characterize the volume of waste that can be using for recycling in biogas by the following data: the manure of cattle – 900 million tons, pig manure – 240 million tons, municipal solid waste – 160 million tonnes (including organic – about 50 million t), sewage sludge – 25 million tons, industrial organic waste suitable for processing into biogas – 35 million tons. It is important to understand that the wastes are accumulating annually and extremely aggravating the environmental problems.

Ukraine has a great potential for the development of biofuel market. A favorable combination of climatic conditions and available workforce are attractive factors for investors because it provides a large number of positive changes to the national economy. Of the total territory of 60.4 million hectares agricultural land covers 41.8 million hectares, including arable land – 32.6 million hectares.

Agricultural land, forests, grasslands and other natural resources provide a large amount of biomass, which can produce a variety of biofuels. Biomass for energy can be used in the direct burning of wood, straw, sapropel (organic sediment) and in processed form as liquid (esters of rapeseed oil, alcohol) or gaseous (biogas – gas mixture, the main component of which is methane) fuel. The conversion of biomass into energy carriers can be done by physical, chemical and biological methods, the last is the most promising.

From biological materials we can get liquid, gaseous and solid fuels. Depending on the use, liquid biofuels are divided as follows: a) for gasoline engines with external mixture formation of the fuel-air; b) for diesel engines with internal mixture formation of the fuel-air; c) the liquid biofuel for boiler.

Liquid biofuels as one of the types of renewable energy are used primarily as motor and stove, and therefore they have direct interest from agribusi-ness. Using liquid biofuels in agricultural production is a real path to energy self-sufficiency and greening field, a step to implement cleaner resource saving technologies in crop and livestock production.

Information on the availability of each type of biomass for energy in Ukraine regions require annual recalculation using appropriate ratios to increases or decreases the total amount of biomass in each of the current year. The reason is the spatial heterogeneity of biomass accommodation, and its variability over time allows the use of such powerful means of spatial analysis as GIS (geographic information system).

GIS allows not only visualize the data on the spatial localization of potential biomass energy resources, but also provides support in making decisions about possible locations and potential production capacity of enterprises with different types of biofuel.

Assessment of availability, spatial distribution and the energy potential of biomass are an important prerequisite for the development of energy strategy and adjustment the state energy strategy.

In Ukraine, in order to produce bioethanol should be used four groups of bio materials: 1) monosaccharides obtained from sugar beet, sugar cane and fruit (glucose, fructose, xylose, mannose, arabinose) directly fermented into ethanol; 2) oligo-saccharides (sucrose) of these crops, which require prior hydrolysis to monosaccharides; 3) polysaccharides (starch), which is produced from grain and potatoes, followed by hydrolysis and fermentation; 4) polysaccharides from wood (cellulose), which also have been hydrolyzed before fermentation.

Important theoretical principles of efficient use of sources of plant material by introduction, breeding, biotechnology, new energy crops are:

• the conversion efficiency of solar energy through photosynthesis of power plants in bio materials by choosing highly efficient producers;

• preserve and enrich the diversity of power plants and optimization of the production process by means of introduction, breeding and biotechnological methods. Basics of designing of new crops and improving existing forms to create productive plants with desired parameters.

Although the production of liquid biofuels is an expensive process, but the experts claim that in assessing the cost of biofuel we must consider its positive environmental effect, namely savings, which do not have to spend to take on the effects of harmful emissions into the atmosphere and other forms of pollution associated with the production and use of traditional fuels. On the basis of US studies it has been established that the liquidation value of the negative effects that occur in the environment and are caused by the production and use of fuel with mineral ranges from 0.1 to 0.4 USD/m^3 of spent fuel. Thus, the total cost balance indicates that fuel derived from renewable biological sources is cheaper in gross economic calculation.

The energy of small rivers. The upper limit of the power equipment of small hydropower is 30 MW. According to the international classification the small hydropower plants include power stations from 1 to 30 MW, mini-hydro – from 100 to 1000 kW, micro-hydro – less than 100 kW.

The total potential hydropower resources of the world is 2,200 GWh, total annual hydropower potential of small rivers of Ukraine – 12.5 billion kWh, or 28% of hydropotential of all rivers in Ukraine.

In Ukraine, there are more than 63 000 small rivers and drains with a total length of 135.8 thousand km, and about 60 thousand of them (95%) are very small – the length is less than 10 kilometers (basins of the Vistula, Southern Bug, Danube, Dniester, Dnieper) .

Replacement of diesel and petrol power plants on micro hydropower plants is profitable even with the positive biological effects. Small reservoirs help to increase the oxygen in the water downstream after passing it through a turbine, which has a positive environmental effect.

Today in Ukraine there are 150 small hydropower stations, 49 of them is in working order, the rest do not work. The current state of small hydro power in Ukraine can be described as poor, outdated equipment, much of it needs to be repaired or is in critical condition. Prospects for the development of small hydropower in Ukraine to 2010 has been determined by the Program of State Support to Development of Alternative and Renewable Energy Sources and Small Hydro and Thermal Energy.

Hydrogen energy. One of the important directions of development of alternative energy is hydrogen energy that solves problems associated with the use of hydrogen as an energy carrier and accumulated. Environment extensive application of hydrogen as an energy carrier in the future allows to predict the occurrence of such industries as hydrogen energy. Hydrogen fully meet the requirements relating to energy – it is easy to accumulate energy, easy to transport, environmentally friendly and energy-intensive. Recent studies show that hydrogen can be used to meet all the energy needs of the industry (85%), everyday life, personal needs (92%).

It can replace the natural gas for domestic use, gasoline – in internal combustion engines, special fuels – in rocketry, acetylene – in welding processes, coke – in metallurgical processes, etc. Currently, 95% of the mass of hydrogen is produced using organic matter – through steam reforming of methane steam-oxygen conversion of carbon gasification, etc. Scientific research in this area showed that the most efficient method of producing hydrogen is the electrolysis of water (even using solar energy or wind power). But modern power resources are insufficient for such production of hydrogen. Hydrogen energy searching cheap primary energy sources and improving the production processes of energy from hydrogen.

In Ukraine, research and development on the accumulation, storage and use of hydrogen are being conducted in Kiev, Kharkov and Odessa.

1.4. The Potential of Alternative Energy Sources in Ukraine

Ukraine has long conducted research, design engineering, investigation and research and industrial work on the use of own alternative energy sources – wind, solar, geothermal, biomass, substandard gas fields. However, widespread commercial introduction of these sources do not meet the current needs of the country in energy, overall energy policy from the standpoint of providing real terms of energy security.

Hydroelectric power in Ukraine is technologically mastered method of electricity production that has enough guaranteed renewable energy and the lowest cost of electricity of traditional types of production. However, after 1984 it almost stopped its development, including small hydropower, which has estimated positive environmental properties among traditional energy sources in the world. In Ukraine, small hydropower development is supported by regional authorities.

The main factors that contribute using the alternative and renewable energy sources in Ukraine are energy shortage; exhaustion of domestic energy resources (reserves of oil and natural gas will be exhausted in 20-60 years); environmental consequences of energy production on thermal power plants, radioactive contamination of areas after the Chernobyl disaster; the share of renewable energy in the national energy production countries seeking to join the EU must not be less than 6%; the high potential of the main types of renewable energy.

Currently, the largest source of air pollution in Ukraine is energetics – an industry, which consumes 40% of fossil fuels, without taking into account also the industrial, municipal and rural energy that is using up to 60% of fossil fuels. The share of Ukraine energy sector accounts for 29% of emissions, including 30% of solids, 63% of sulfur dioxide and 57% of nitrogen oxides. Even excluding the effects of the Chernobyl disaster, specific pollution per unit in Ukraine is one of the largest in Europe. The analysis of the spatial distribution of disadvantaged regions shows that here we can effectively operate the installations that use AES.

The total demand for energy, the share of traditional energy sources and energy consumption of AES in Ukraine until 2010 have been defined by the Program of State Support to Development of Alternative and Renewable Energy Sources and Small Hydro and Thermal Energy for 2000-2010.

Stocks of solar energy in Ukraine are 1000-1400 kWh/m ^{2}, wind energy – 80 kW/m ^{2} , wave energy of Black Sea – 10 kW/m ^{2} . Wind power has developed primarily in the Crimean Peninsula, on the shores of the Black and Azov Seas, near the Carpathian Mountains. In southern Ukraine there has been justified the construction of combined solar-thermal power plants (STPP).

Use of AES in planned volumes will significantly reduce the amount of harmful emissions into the environment and, therefore, reduce the cost of their disposal when using fossil fuels. Potential of AES in Ukraine on the main lines of their development is shown in table 1.2.

Table 1.2

The potential of alternative energy sources in Ukraine

Alternative Energy Sources	Annual capacity					
	general		technical		economically viable	
	bln. kW · h.	million tons s.f.	billion. kW · h.	million tons of s.f	bln. kW · h.	million tons of s.f
Wind	270.0	97.2	30.0	10.8	3.8	1.2
Solar power	720000.0	88400.0	3460.0	720.0	5.4	0.9
Geothermal energy	438.0	50.0	262.8	30.0	180.0	21.0
Small hydro	12.5	4.5	8.3	3.0	3.7	1.3
Unconventional fuels	165.2	20.3	165.2	20.3	165.2	20.3
Energy environment and dropped energy and technological potential	2806.7	421,2	1135.0	170.4	96.3	14.5
Total	123692.4	88993.2	5061.3	954.5	454.4	59.2

Ukraine has great thermal zones at depths of less than 4 km that are concentrated in the Crimea and the Carpathians. The total groundwater potential of these regions is 1.5 million m^3 per day, or 550 million m^3 per year. According to the calorific value the resources of geothermal energy in Ukraine exceeds the conventional fuel reserves.

Agrarian and industrial production of Ukraine has significant biomass potential that are available for energy production. Biomass is renewable, environmentally friendly feedstock for biofuel production and further use for different purposes. As biomass is carbon-neutral fuel, its use do not contribute to the global greenhouse effect. According to expert estimates, the annual theoretical biomass potential is about 45 million tons. e.f., technically accessible – 32 million tons. e.f., and economically viable – 24 million tons. e.f. (tab. 1.3).

The main components of the energy potential of biomass is energy crops and agricultural waste. Among the last ones the waste from sunflower production (stalks, husks, heads) has the greatest economic potential; corn offal (stalks, leaves, cobs rods) has slightly lower potential. Straw of cereals and rape straw occupy third and fourth places respectively.

Table 1.3

The annual energy potential of biomass in Ukrainian agribusiness (according to STC "Biomass")

Type of biomass	Annual capacity (mln.tons of s.f.)		
	general	technical	economically viable
Cereals straw	10,39	5.21	1.34
Rape straw	1.65	1.15	1.15
Maize and sunflower waste (stalks, leaves, cobs rods, baskets, husk)	9.97	6.85	5.65
Feedstock for biodiesel (rapeseed, sunflower, soybean, etc.)	0.78	0.50	0.25
Feedstock for bioethanol (grain, molasses, etc.)	2.33	2.33	0.86
Feedstock for biogas (livestock manure, corn silage, food waste, etc.)	5.63	4.02	2.13
energy crops (poplar, alder, willow and others)	14.58	12.39	12.39
TOTAL	45.33	32.45	23.77

Thus, we can conclude that the most promising type of alternative energy in Ukraine is the production of biofuels. This is facilitated by a strong natural resource potential and agro-climatic conditions of our country.

According to the energy strategy developed by the Institute of bioenergy crops and sugar beet NAAS, the main component of the energy strategy of Ukraine is the use of biomass for the production of biofuels (Fig. 1.5).

Decontamination of waste biomass often ranks first place in the process of justification of implementation of bioenergy technologies in order to ensure environmental protection: animal waste and urban waste water processing include not only decontamination of dangerous microorganisms, worms and seeds of weeds that fall to the soil, surface and groundwater, but absence of air pollution in areas of accumulation.

Solution of farming issues are no less important factor for bioenergy; and in this cases should take into account not only increases in yields through high-quality fertilizer, but also reduction of harmful microorganisms and unwanted vegetation in fields.

The efficiency of biomass processing in energy production can be reached only with rational parameters of processes and machines for agriculture, which convert biomaterial. Each type of biomass can give a wide variety of products. For example, the production of biodiesel from waste oil seeds (straw, husk and cake) can

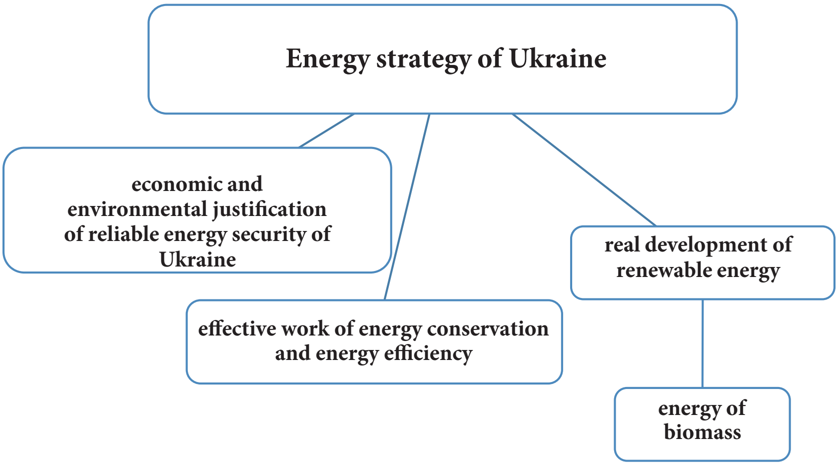


Figure 1.5. The Main Directions of the Energy Strategy Development of Ukraine

give a number of products with commercial value. Even a simple straw burning in boilers provides a solid heat and back the ash into the soil as fertilizer. Production and use of biogas and accompanying high quality organic fertilizer, producing secondary energy resources of agricultural raw materials, create conditions for disposal at the present level of biological waste agricultural production.

Thus, the energy efficiency of bioenergy is certainly high enough to allocate it in a separate direction of the energy sector. Ukraine has enough power potential of virtually all types of biomass and sufficient scientific, technical and industrial base for the development of the energy sector, and provide comprehensive use efficiency of bioenergy resources of Ukraine.

1.5. The History of World Bioenergy Development

Since the birth of civilization the human as every alive creature uses the energy that comes from food of plant and animal origin. This energy can accumulate in the body or just be spent for the development and functioning of a living human body, metabolic processes, use of muscle power to perform movements of separate body parts, and the whole body.

The man began to use energy in order to create simple tools and applied it in crop production, livestock, home. Biomass used by people since man first discovered fire. Wood was the first form of biofuel that people used for cooking and heating for a long time.

In 18th century, wood was replaced by coal, and in the 60s of 19th century – by oil, later – by gas. Since the second half of the 20th century people resorted to energy from nuclear power. Today scientists are working on procuring energy of thermonuclear synthesis that occurs in special chambers, where the plasma is.

The first attempts to use wind power and water were made by sailing ships, wind and water mills.

History of liquid biofuels has its origins from the 19th century. One of the first researchers who started using biofuel was Samuel Morey, who proposed an engine model developed by him in 1826. He fueled it with a mixture of turpentine and alcohol.

The next step in this direction was taken half a century later, in 1876, by German inventor Nicholas Otto. He created four-stroke cycle internal combustion engine that worked on bioethanol.

Biofuels have been used by a famous American inventor – Henry Ford. In 1896 he created a vehicle with an alcohol engine. Ford believed the use of alcohol is advantageous not only from a technical but also from an economic point of view.

The first diesel internal combustion engine was designed by Rudolf Diesel and presented at the World Exhibition in Paris in 1890. It worked on vegetable oil.

It has been found significant reserves of oil at the beginning of the 20th century. Its production volumes have increased, gasoline began to fall in price rapidly, and as a result, interest in biofuels for a certain period of time disappeared.

Later ethanol as fuel was actively used in many countries during the First World War (1914-1918). After the war, in the 20s, a mixture of gasoline and alcohol became widely used in the United States and many European countries.

Now, in the world, there're fastest growing phenomena that violate civilized course of life. Now we can observe exhausting of traditional energy sources, increasing production cost, intense environmental pollution, destroying of the biosphere, forming the excessive amounts of organic waste from industrial, agricultural and domestic origin. Overcoming all these problems must be accelerated, or humanity will face the threat of extinction.

The projected exhaustion of the world's major fossil fuels (oil and gas in the next 40-50 years) and environmental factors induce the majority of developed countries to look for alternative and non-traditional renewable energy sources.

Oil prices steady increases in world became the catalyst for these searches. Based on the experts of UNDP, the share of renewable energy in the global fuel and energy balance in 2050 could reach 50%, as predicted by the World Energy Council – to 80-90% at the end of this century.

Now the measure of alternative energy usage in such country, as Sweden, is 51%, Norway – 45%, Austria – 33.0% of Denmark – 26%.

Biological energy or biofuel (biodiesel, bioethanol and biogas) is becoming more and more widespread among renewable energy sources.

Annual plants with high content of sugar and starch (corn, potatoes, sugar beet, maize) and oilseeds (rapeseed, sunflower, soybean, oil flax) are considered as agricultural energy crops in the European climate zone. They can be used as a feedstock for biofuel production used for ethanol.

Except sugar, starch and oilseed crops, we can use perennial grass as biological feedstock for biofuel production. These are such plants as Miscanthus giganteus (cane), Sorrel Fodder, Sida hermaphrodita Rusby, Helianthus tuberosus and others.

From agro-technical point of view there is no difference between growing energy crops and its growing in food industry. The difference involves the varieties that are used for energy purposes: they may be transgenic varieties (mainly rapeseed in terms of EU and soybeans in terms of US).

As for the benefits of biofuels, the US academic institutions tend to the view that biofuels, especially corn and cellulosic ethanol is the only renewable liquid fuel option for the transport sector, which can be easily integrated into fuel oil. Production and use of biofuels could provide significant advantages to strengthen national energy security, economic growth and environmental quality.

Biofuel industry will create new jobs and will increase energy supplies to support national and global prosperity. By 2014 the US ethanol industry created 500,000 workplaces throughout the economy and provide an additional 2 billion dollars of tax revenues to the federal government, state governments and local authorities. According to conservative forecasts of future growth, every billion gallons of produced ethanol will create an additional 10 to 20 thousand workplaces.

Among the economic benefits, US experts emphasize the state attention on thought that the biofuel industry could revive the rural economy. Biopower culture and agricultural residues can be important for farmers, create new source of income and reduce dependence on public funds allocated to support agriculture. Economic analysis, jointly conducted by the Ministry of Agriculture and US Department of Energy showed that the transfer of some arable land for bioenergy crops can enhance low prices for traditional crops by 14% and increase annual net income of farmers at $ 6 billion.

Ukraine's integration into the world economy and its European choice, supported by the international community, provides our country's achieving the European living standards, including energy efficiency.

Low energy efficiency was one of the main factors of the crisis in the Ukrainian economy. In the first half of the 90s the energy component cost almost tripled in the cost structure of industrial production, reaching 42% of the material costs for these products.

Significant energy efficiency of the national economy is one of the main ways of ensuring the safety of budget revenues, increasing competitiveness of domestic products both in domestic and foreign markets, social issues.

Thus, introduction of energy saving technologies can reduce energy imports and neutralize political pressure on our country from exporting oil and gas. In addition, reducing the energy component of production costs allows Ukraine to become competitive in foreign markets.

Therefore, special attention should be paid to the further development of alternative and renewable energy sources. Their unconditional advantage is inexhaustible and environmental cleanliness. There is no coincidence in the European Union moving to biomass, wind, sun and water. The current situation in Ukraine with provision of energy in terms of domestic production of energy considering dependence on neighboring countries urgently put the problem of finding alternative fuels. And the environmental damage from vehicles emissions that run on gasoline and diesel fuel, become more tangible.

Road transport plays a leading role in the transport of goods. According to the Ministry of Energy and Coal Industry of Ukraine, now in our country there is about 150 cars per 1000 people. By 2030 through increasing personal wealth the amount of cars in Ukraine can reach the level of developed countries of Eastern Europe and will be approximately 38 cars for 1000 people.

Vehicle fleet forecast of Ukraine indicates a steady increase in the number of cars and fuel consumption. So in the production and consumption of car fuel there is a problem of resource conservation and alternative sources, and it will be more crucial, of course, along with solving problems of environment impact. The use of renewable energy is strategic issue for the development of Ukraine's economy in general and agricultural and industrial complex in particular. This is due to the number of factors:

1. Ensuring energy security and reduction the dependence on energy imports.
2. The development and stability of the agro-industrial complex.

3. New jobs and increase in revenues to budgets of different levels.
4. Improving the environmental situation.

However, the pace of biofuel market development in Ukraine is far behind the needs of the state. And it is despite the fact that this important industry has been launched in Ukraine in 1997 when the Vinnytsia regional state association of alcohol and alcoholic beverage industry have reconstructed two (Bar and Haysyn) distilleries. In the same year the plant started to produce biological additives, called High-octane oxygen-containing admixture which is now known as ethanol.

On July, 1998 on the basis of Vinnytsia Regional Alcohol Association was held scientific conference under the leadership of the Prime Minister, with the participation of ministers, heads of state committees, managers, researchers, which identified the need for rapid development of biofuels on world experience, however, such strategic decisions have not found practical support.

Ukrainian alcohol industry fully meets domestic needs in alcohol for making alcoholic beverages, using only 30% of its total capacity. In cases of favorable economic policies 70% of "free" fascilities of distilleries for ethanol production, Ukraine could become one of the important producers of fuel oxygenates based on ethanol in particular and biofuels in general.

Based on soil and climatic conditions of Ukraine, the feedstock for biofuels can be listed as follows: corn, sugar beets, wheat, triticale, various types of sorghum and millet, canola, sunflower, agriculture and forestry waste, as well as miscanthus, poplar, stems and sunflower husk. Of course, champions of the energy storage per hectare in our environment are potatoes and sugar beets.

Establishment of biofuel production is connected with the purches in the engineering industry. Creation of production with deeper processing of feedstock would have the additional effect on reducing energy production; opportunities for farmers to produce biodiesel; produce high quality feed high in protein; use the by-products of biofuel production such as meal, glycerine, dry grain vinasses, organic fertilizers.

Solving the problem of renewable energy sources is a national issue. Ukraine has the opportunity to fulfill the public mission – to return to the fields lost crops and improve animal husbandry, resume the sugar and ethanol businesses, Engineering and technical personnel that will bring considerable profits for the state and people directly. Having start Ukrainian production and use of biofuels, will have its own fuel profitable production, employment, labor force, which ultimately solve a number of problems in Ukraine. The main barriers to the development of biofuels market are shown in Fig. 1.6. The decision on construction the biofuel plant requires a comprehensive analysis of many factors:

1. Risk assessment of investment (political situation, economic stability, the level of economic freedom, possible change of markt conditions, the availability of government support, legal and regulatory framework).
2. Estimation of commodity software industry (diversification of raw materials, availability of sufficient arable land, agro-climatic conditions).
3. The choice of production capacity and technological schemes of production.
4. The choice of plant location (infrastructure, logistics, competing production).

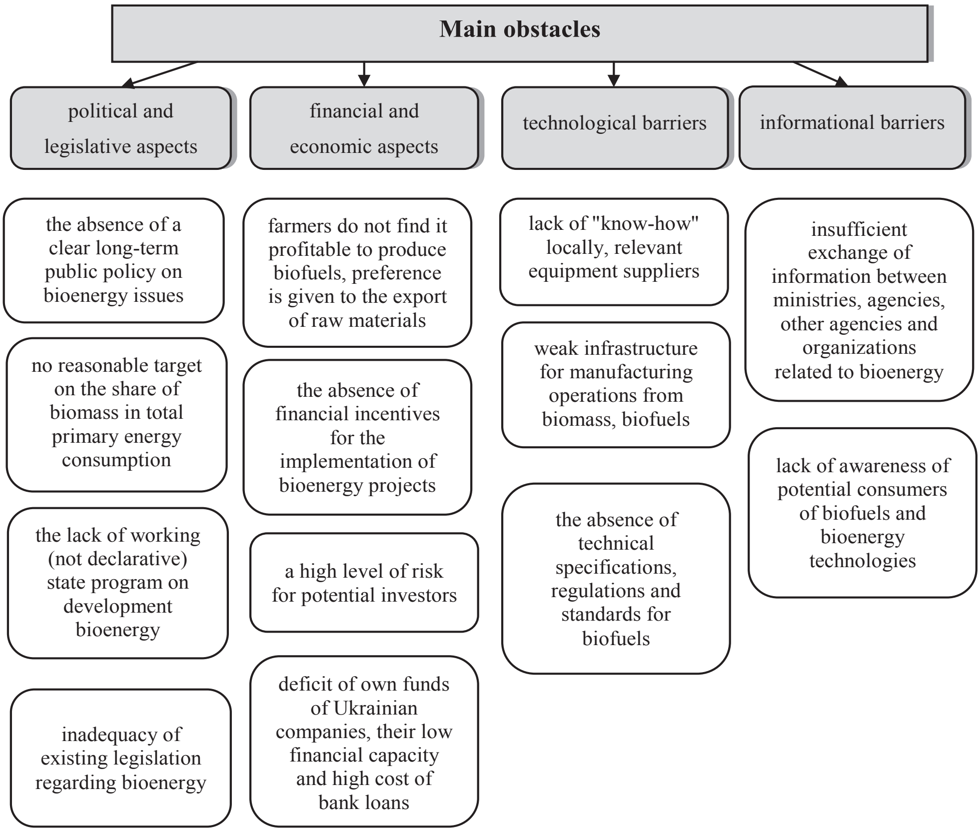


Figure 1.6. The Main Barriers of Biofuels Market Development in Ukraine

Factors that determine the necessity of the production and consumption of biofuels in Ukraine are the following: exhaustion of fossil fuels, dependence on imported energy resources, permanent increase in their cost, environmental degradation. However, the presence of natural resources makes it possible to grow a wide range of crops that can be used as a feedstock for biofuel production.

1.6 Socio and Economic Need and Importance of the Biofuels Market in Ukraine

Today, oil is the main derivative for the production of transport fuels in the world. It belongs to fossil energy sources, so its reserves are exhaustive and non-renewable. Researchers at leading universities, international organizations and oil companies publish different data on oil reserves in the world and predict when they will be exhausted.

As to the possible timing of depletion of oil reserves there are pessimistic and optimistic forecasts. Pessimists believe it will occur in 20-25 years and optimists – in 50-70 years. All, however, agree on one point, which is that human development is only possible with finding new sources of energy and new types of bio-saving technologies and materials. Pessimistic forecasts of a complete depletion of oil and as a result of the global crisis may not come true, if we can find new sources of oil extraction or take decisive action to limit its consumption.

Consumption of oil in the world lately is constantly growing. This was facilitated by many factors, including the increase in population and vehicles, the development of STP, automation of production, improve the quality of life that affects the increasing number of different kinds of traffic and growth in energy consumption for personal needs (heating, lighting, use of various devices). Thus, according to the Organization for Economic Cooperation and Development (OECD), the last 10 years the world's population has increased by 13%, the number of cars by 50%, and transportation distances increased by 65%.

Only in one century humanity has lost the bulk of the most valuable hydrocarbons that was created in the bowels of the Earth for hundreds of years. And the oil is being consumed in extremely uneconomically way and more than half of its production is used for the production of motor fuel for subsequent combustion in engines and power plants. It is important to remember D. Mendeleev's insightful warnings that he made in 1884, "Using oil as a fuel is the same as inflame the oven with banknotes".

Uncontrolled and constantly growing of oil extraction and use of oil fuels leads to many adverse environmental effects that threaten human health and the environment, namely climate change, acid rain, oil spills, explosions and fires at oil platforms.

The dynamics of the cost of traditional fuels are constantly rising. In particular, the price of Brent crude oil increased steadily since 1998. The exception was only in 2008, which was characterized by the decline of the global economy. In 2013, oil price averaged $ 115 per barrel. Since September, 2014 oil prices began to fall rapidly and reached a historic minimum – 89 dollars per barrel. In May 2017 the price was 49.43 dollars per barrel (fig.1.7). However, this drop in prices had no reflection in the cost of gasoline and diesel fuel in Ukraine (fig.1.8).

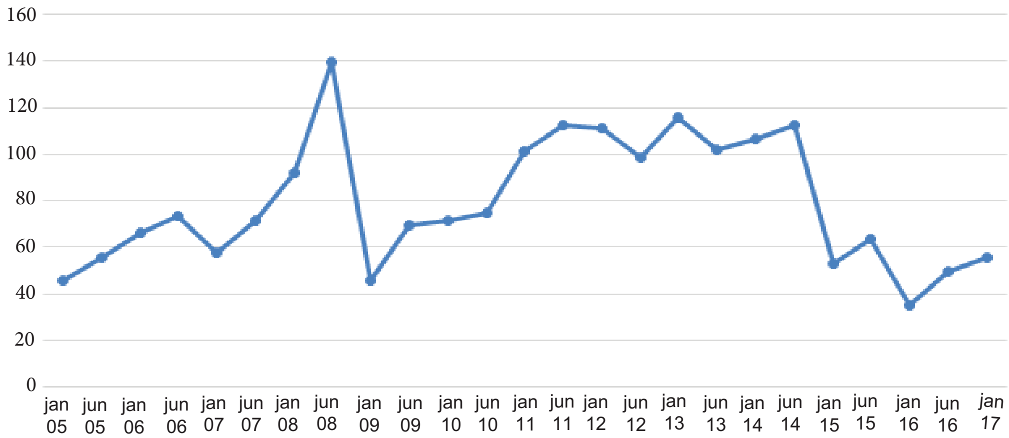


Figure 1.7 Brent Oil Futures Historical Data

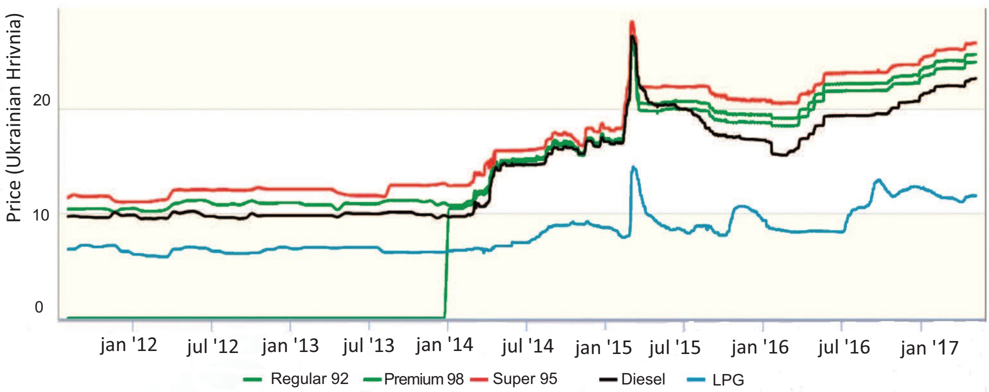


Figure 1.8 The Trand in Gasoline Prices (UAH)

Even if somebody will find new, previously unknown reserves, there will be rapid pace of global oil consumption until exhaustion of its reserves, possibly by the end of the 21th century. Instead, all are unanimous in one thing: the development of mankind is possible only with the involment of new sources of energy and new types of energy-saving technologies.

After analyzing the dynamics of prices for gasoline and diesel fuel in Ukraine and abroad, it is clear that their price will not decrease in the near future, but on the contrary – will increase. The rising cost of energy carriers leads to higher prices of absolutely all goods and services, because they are closely related to the energy component. Considering the limitations and exhaustion of oil reserves in the world and in Ukraine in particular, the existing dynamics of the rising cost of imported oil and gasoline prices and diesel fuel in Ukraine, the experience of advanced countries in the development of biofuels, our country must quickly switch to the production of alternative fuels.

Production of biofuels has increased significantly in recent years worldwide. In Ukraine, this trend is increasing because of the need to overcome power deficit, reduce dependence on oil imports and availability of natural resources potential for biofuels production.

As for the economic and social need for the formation and development of the biofuels Ukraine there are several reasons, starting with considerations of energy security, diversification of national production, innovation support and ending with economic and social efficiency market, development of biofuels based on high motivation growth of the agricultural sector, positive social changes, the growth of employment in rural areas and environmental security through renewable energy sources.

Production and use of biofuels in agriculture sphere in Ukraine are objective conditions to create new jobs, increase rural employment, increase production efficiency and welfare of farmers. For the vast majority of processing enterprises located in rural areas, and for some localities they are the main taxpayers in local budgets. At their base it has been built social infrastructure of villages and irregular work of processing plants significantly affects the most vulnerable people – leads in particular to problems with providing heat and electricity in kindergartens, schools and residential buildings.

Solving the problem of dynamic biofuels market requires the establishment of energy crops as feedstock for its production, use of agricultural land is suitable for cultivation of energy crops without reducing the level of food production. This subject is constantly under the discussions: what is more important – food or biofuels? This issue is very complicated, because on the one hand, providing the population with food is a priority of the government, on the other – energy independence is the foundation of state sovereignty. Therefore, analysis of opportunities for growing biomaterial for biofuels production should be performed considering the situation with existing nutritional needs and available sources of the fuel as the state in general and its individual regions.

The agricultural sector of Ukraine has significant potential for growing feedstock required to produce bioenergy. Currently, agricultural land in Ukraine consists of 41.9 million hectares, including arable land – 32.5 million hectares. Per capita in Ukraine (total population of 45 million people) are 0.93 hectares of agricultural lands, including 0.72 hectares of arable land, while the European average which these figures are 0.44 and 0.25 hectare respectively.

According to the Ministry of Agrarian Policy and Food of Ukraine, the annual demand for agriculture in petroleum products on average is 1 million 870 thousand tons of diesel fuel, 620 thousand tons of gasoline. At prices of 2000 year for the purchasing of such quantities of diesel fuel and gasoline it has been spent 4 billion 363 million UAH, in 2017 – 53 billion 451 million UAH (tab. 1.4). Thus, fuel costs increased in 13 times, while the price of sugar beet, cereals, meat and milk – in 3,3-4,1 times. Obviously, such a disparity in prices reduces the profitability of agricultural production.

Table 1.4

Wholesale selling price of gasoline and diesel fuel

Indicators	2000	2014	05/2017
Cost of gasoline, UAH per ton	1,850	17,000	24,390
Consumption of gasoline, thousand tons	620	620	620
Cost of diesel fuel, UAH per ton	1,720	13,500	22,830
Consumption of diesel fuel, thousand tons	1,870	1,870	1,870
Total costs, billion UAH	4,363	35,785	57,814
The increase in costs compared to 2000, billion UAH	-	31,422	53,451

In view of these problems, which have arisen at this stage of the development of state, production of biofuels is one of the key catalysts of new global trends in the agricultural sector of Ukraine, which will promote its sustainable development.

The urgency of stabilizing Ukraine agriculture by enhancing the production of biofuels has led to fundamental research in this area by many universities and research institutions of Ukraine. So to intensify work in the research and implementation of advanced biotechnology on the basis of Vinnytsia National Agrarian University and the Institute of bioenergy crops and sugar beet National Academy of Agrarian Sciences of Ukraine was created educational-scientific-industrial complex «All-Ukrainian scientific-educational consortium.»

To increase its own production motor fuels Ukraine should include adequate replacement of traditional motor fuel for motor mixtures of different types of fuel additives, one of which is ethanol that can be used as an admixture to petroleum products. The economic aspect of the use of high-oxygen-containing additives to the gasoline or bioethanol (ethanol fuel) is to reduce the cost of fuel, the price of which is increasing in the world market.

Another way of solving the problem of getting enough of their own motor fuel in Ukraine is the use of rapeseed oil for biodiesel production (biodiesel). Due to the significant content of organic compounds that are harmful to the human body in rapeseed oil obtained from rapeseed, in which the content of erucic acid and glucosinolates is high, its use in the food industry was prac-tically limited. Considering the fact that its average calorific value (33.1 MJ/l) is only slightly lower than diesel fuel (35.1 MJ/l), the use of rapeseed oil as fuel is appropriate and is important for the energy sector.

It has been planned in Ukraine to increase rapeseed production annually up to 7.5 million tons, which can provide over 2.5 million tons of biodiesel (60% of the annual needs of agriculture sector of the state).

It is expected that in the future production of fuel ethanol (according to the program for the development and use of alternative renewable energy and small hydro and power system, approved by the Cabinet of Ministers of Ukraine from 12.31.1997 No. 1505), will increase annually with the involvement in the production process the capacity of most existing distilleries and sugar plants and capacity in agriculture sufficient resource base.

Practical experience of forming biofuel market in European countries shows that biomass has the greatest value among renewable energy sources: carbon-containg (vegetation, wood chips, sawdust, seaweed, grain, paper, packing containers) and sugar-containg (sugar beets, sugar cane, cane, sorghum). Its share in liquid biofuel production will increase by 40-60, electricity – 10 times and heat – twice.

It is clear that only biomass can not satisfy the growing needs of modern civilization, but even 6-10% of their demand provided through appropriate utilization of organic matter deserves attention. Biomass as a renewable energy is used by mankind from ancient times. Currently in the total world energy consumption (82,3 trln of MJ) the share of biomass is 2.1 trln of MJ, fuel oil – 40.1 trln of MJ, gas – 21.9 trln of MJ and nuclear energy – 2, 9 trln of MJ. In the next decades from an energy utilization of biomass is expected to increase to 5,3-10,6 MJ trillion, but it is doubtful that this level is reached.

The energy attractive plants of European soil-climate zone include the following:

1. one-year crops with high content of sugars and starches (sugar beets, corn ear, corn, potatoes) for industrial bioethanol production;

3. oilseeds (rapeseed, sunflower, soybean, flax oil) for oil and biodiesel production;

4. perennial grasses (miscanthus gigantus or cane, interspecific hybrid sorrel – rumeks, switchgrass, artichoke (Helianthus tuberosus), Sida hermaphrodita Rusby and others).

High level of cellulose allows us to use them combined with fuel, paper industry and as insulation material.

Great expectations also impose the cultivation of genetically modified plants, including corn hybrids on separate tracts of land.

Among the wide variety of biofuels dominant role is given to liquid fuels. That is why it is important to determine the economic feasibility of each type of energy crops for industrial processing into biofuel.

At this stage, the most important task for biomaterial market development in Ukraine are the following: development and modern technologies of energy crops cultivation, which are planned for industrial processing into biofuel, increased production culture, providing insurance protection for crops, technical modernization of agro output for optimal power development and implementing regulations, harmonized with the EU legislation. At the same time, it is necessary to conduct economic studies and calculations concerning the further development of agricultural industries that could transform part of the production potential into the development of crops for biofuels processing. In any cases, we should strive to change and resulting changes should cause the increase of economic efficiency and will not create obstacles to food security.

Through organizational work on forming the biofuels market in Ukraine, the state should, as it is in the leading countries for the production of biofuels, introduce temporary tax and other incentives to biofuel producers.

One of the factors of braking development of the biofuels market is the lack of energy crops as biomaterials for production of fuels.

For a substantial increase the amounts of fuel and energy produced from alternative and renewable energy sources in the energy balance of Ukraine, organizational work should be conducted hard in order to build renewable energy facilities for the most promising technological directions for getting mixed liquid biofuels.

In order to overcome the obstacles to widespread use of fuel additives based on ethanol, biodiesel and ensure the creation of adequate export volumes of fuel in Ukraine we have to:

- develop the strategy – a plan of actions for at least 10 years for sustainable industry development of biofuels. The plan should be consistent, systematic and clearly define the effective use of public funds within the proposed ways to reform in this area. To create biofuels market in Ukraine and attract powerful investors there is a need of clear and stable policy, underpinned by a functioning legislative and normative bases;

- develop and implement a set of measures for the development of intensive cultivation of high-tech plants (grain, oil, starch and sugar) and the required volume of biomass from other crops for biofuels and other energy sources that can be used in cogeneration plants for process and electrical thermal energy and achieve waste production;
- expedite arrangements for entering Ukraine on a new promising market of clean renewable energy consumption, including fuel ethanol, biodiesel, various fuel components etc.

create energy independent agricultural enterprises in contaminated territories of Ukraine in order to obtain raw rapeseed for biodiesel production and decontamination of the land and return them to normal agricultural use.

Ukraine has collected enough information and legal databases for scientific and theoretical support of the main directions of renewal energy sector through the planned use of biofuels, in particular liquid. This should establish a mass production process of equipment at the existing engineering and mechanical plants. For bioethanol production in Ukraine is economically reasonable to form market of energy crops: sugar beets, grain crops, including corn, sugar beet and potatoes processing residues, and for biodiesel – rapeseed, soybean and sunflower.

To maximize the economic efficiency of the production of biofuels we should create regional zones of concentrated energy crops on certain acreage, build the needed infrastructure.

Given the above lead to the following conclusions. A favorable combination of climate, the great potential of the agricultural sector and available workforce in Ukraine make extremely attractive the development of the market for biofuels. In the perception of potential investors biofuels market development in Ukraine will make positive changes in efficiency in business and at the same time economic and social feasibility of the national economy as a whole. Moreover, it will only be possible with political will, involving key players in the market, ranging the initiators of the reforms from government, automobile manufacturers that provide warranties on vehicles using biofuels, oil companies and businesses agricultural producers who actually work with all of agents of feedstock producers.

Biofuel production in Ukraine will not only reduce dependence on energy imports but also improve economic and environmental situation. Fertile soils and production facilities enable Ukraine to grow and process much more agricultural products than now. Establishing the biofuel production in Ukraine will help to create jobs, especially in rural areas where there is significant unemployment problem. In addition, the construction and operation of plants for biofuel production will provide additional revenue.

In our country we have a unique chance to use international experience to explore the practical application of the ideas of biofuels production in the most successful countries. It can use the valuable experience of EU for successful implementation of the policy of mandatory use of biofuels. The study of the practice and its adaptation to the political and business realities of Ukraine will be the first important step towards launching a long-term and fruitful cooperation between key actors in this field.

Basic definitions and concepts. *Energy. The energy sector. Energy security. Fuel and energy balance. Traditional energy sources. Energy. Petroleum products. Nuclear power. The gas transportation system. Power plants. Hydroelectricity. The coefficient of performance (COP). Resource. Provisions. The material base. Solar power. Wind power. Geothermal energy. Hydropower. Hydrogen energy. Bioenergy. Biofuels. Biomass. Bioethanol. Biodiesel. Biogas. Potential. Feedstock. Market biofuels. The environmental situation.*

Test questions and tasks

1. What is the source of energy and what importance they have for life?
2. What is the nature of energy security?
3. In which countries the largest reserves of fossil fuels are concentrated?
4. What trends will be inherent in energetics in the 21th century?
5. What are the disadvantages of conventional sources of energy?
6. What provides basic measures for the reduction of anthropogenic emissions and increasing absorption of greenhouse gases?
7. Describe the main reasons that necessitate biofuel production in Ukraine.
8. What are the knowledge of the trends and prospects of traditional and renewable energy?
9. What are the difference between traditional sources and alternative energy?
10. Describe the potential of alternative energy sources for the main directions of development.
11. What are the advantages and disadvantages of alternative energy sources?
12. What are the main factors for using the ARES in Ukraine?

13. Describe the history of bioenergy in the world.
14. What is biomass and how is it received?
15. What importantance the search for alternative energy sources has?
16. What factors cause the increase in oil consumption in the world?
17. What are the consequences from uncontrolled and increasing oil production?
18. What is the need of biofuels market socio-economic development in Ukraine?
19. What are the main tasks for the development of biomass production in Ukraine?
20. What measures should be taken to overcome obstacles to the widespread use of biofuel in Ukraine?

CHAPTER 2
REGULATORY FRAMEWORK FOR BIOTECHNOLOGY PRODUCTION

Key issues

2.1. Global Measures Against Climate Change

International organizations, primarily the UN, aiming at mitigating the effects of climate change, initiated the development of 'Framework Convention on Climate Change', which was signed by 155 countries in Rio de Janeiro in 1992.

The purpose of signing the Convention was preventing global warming and the associated negative consequences. The main purpose of the Conven-tion is 'stabilization of greenhouse gas concentrations in the atmosphere at a level that prevents dangerous anthropogenic interference with the climate system'. The Convention contains non-quantitative commitments, so in order to define the quantitative measures the supplementary document has been developed – The Kyoto Protocol.

The Kyoto Protocol is an international agreement on the limitation of emissions of greenhouse gases. The main purpose of the agreement is to stabilize the level of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system of the planet.

The Protocol commits the developed countries and countries with economies in transition to reduce or stabilize greenhouse gas emissions in 2008-2012 to the 1990 level.

Protocol was adopted in Kyoto on December 11, 1997. The period of signing began on March 16, 1998 and ended on March 15, 1999. The Kyoto Protocol came into force on February 16, 2005.

Today the Protocol has been signed and ratified by 191 countries, including most of the industrialized countries except the United States, which have signed but not ratified the treaty. According to The Kyoto Protocol the member countries are obliged to reduce annual greenhouse gas emissions in the period of 2008-2012 to an average of five percent against the levels of 1990.

Special obligations to reduce emissions has been taken by Japan – 6%, USA – 7%, and the EU – 8%. In the EU, some countries various restrictions were imposed. In particular, in June 1998 the EU-Environment Ministers obliged Austria to reduce emissions by 13% (compared to the northern European Union countries committed to achieve their maximum reduction by 28%).

Since August, 1997 Ukraine has become a party to the Convention. It signed the Kyoto Protocol to the Convention on March 15, 1999, and the Verkhovna Rada of Ukraine ratified it on February 4, 2004.

The obligations of Ukraine according to the Kyoto Protocol:

– improving the efficiency of energy use;

– protection and enhancement of sinks and reservoirs of greenhouse gases;

– promotion of sustainable forms of agriculture in the context of consideration of climate change;

– research, development and promoting the widespread use and introduction of new and renewable energy, carbon dioxide sequestration technologies and advanced and innovative environmentally sound technologies;

– progressive reduction or phasing out of market imperfections, fiscal incentives, tax exemptions, subsidies and duties, contrary to the objectives of the convention in all areas that are sources of greenhouse gas emissions;

– encouragement of appropriate reforms with a view to promoting policies and measures which limit or reduce greenhouse gas emissions;

– measures to limit and/or reduce greenhouse gas emissions;

– limitation and/or reduction of methane emissions through its recovery and reuse in waste management, as well as in the production, transport and distribution of energy.

Under the Kyoto Protocol, there are two types of quotas in Ukraine. The first – the total emissions reduction could be conditional tons. The second – when working companies use the latest technologies and reduce the amount of harmful emissions, they can independently manage the funds received from the reduction of emissions.

The average cost of 1 ton of first group conventional emissions ranging from 3 to 7 euros, the second – from 10 to 17 euros. Currently the state has a quota of 4.5 billion tons of emissions that are registered in the Treasury. The amount of money that Ukraine would receive from the sale of Kyoto quota is 18 billion euros.

From 2009 to 2012, the Government of Ukraine managed to sell 47 million assigned amount of units. The selling price was approx. 10 euro per unit of transferred GHG emission quotas, so the total amount of funds received by Ukraine through the mechanism of the Kyoto Protocol emissions trading was 470 million of euros.

The areas of projects implementation under the international emissions trad-ing of Kyoto Protocol in Ukraine were approved by the buyer country in the relevant Green Investment Scheme Guidelines. Thus, the following categories of activities were selected for funding:

- Energy conservation,
- Fuel switching for low environmental burden,
- Utilization of Mine Methane,
- Renewable energy,
- Activities for reduction of greenhouse gases emissions other than carbon dioxide (CO_2),
- Activities for environmental protection (e.g. pollution reduction activity).

2.2. U.S. Regulatory Legal Acts on Alternative Energy

The issue of sustainable and predictable provision of the United States economy, as well as the strategic energy resources are becoming an increasingly important element of the US foreign policy. The political leadership of this country considers it necessary to implement a foreign policy strategy, which will allow them, as well as their strategic allies constantly reduce its dependence on imported energy, particularly oil and gas. That is why the highest US government pays great attention to such issues like the creation of favorable conditions for research and implementation of alternative energy sources, as well as an international dialogue on the wider use of new energy supply routes.

In addition, representatives of the US Administration of the President believe that the energy security of the country depends on the size and intensity of the international dialogue on energy issues.

One of the main goals of the US energy policy is to ensure the US economy with a reliable access to energy sources, and for the US diplomacy – to create safe conditions for the transportation of energy resources from the region of production to the final consumer. However, the dynamic of the oil market, globalization and the increasing integration of the natural gas market increasingly affect the energy security of both the United States and other countries that are heavily dependent on imports of basic types of energy.

At the end of 1973, for the first time in peacetime industrialized states were forced to think about the importance of saving resources. The reason for this was the embargo, which the Arab-exporting countries have introduced to supply oil to the West. Oil prices have been doubled. European countries and North America entered a period of economic crisis. This led to a fundamen-tal change in estimates. If before the embargo new energy sources were thought to appear before they were needed, then in the mid-1970s it became clear that energy reserves were exhausted. After the onset of the oil crisis, the debate about energy savings has been one of the important issues of public policy. Previously economically saving vehicles and energy-saving technologies appeared at the event, then – many states and economic sectors announced the priorities of such developments. The US President Jimmy Carter for the first time in history made energy savings one of the main goals of his policies. He was confident that the US faced a noticeable shortage of energy and is very de-pendent on its imports that threatens national security. Carter initiated a large-scale propaganda campaign aiming to encourage Americans to save energy. He gave a speech in which he called for reducing temperature in residential and working areas to reduce the amount of energy consumption. But this calls were in vain: in the US the energy consumption fell slightly, but not significantly.

It had his own reasons. So for the inhabitants of the United States it was difficult to abandon the massive use of private cars, in spite of the high cost of gasoline – the reason for this is not their contempt for public transport, and the chain of events. In 1940-1950's there was a mass migration in the United States – urban residents started to move to the suburbs. There was a lot of reasons for this. So since 1920's the car was no longer a luxury but has become affordable for the majority of the country's working population. In the late 1930s it has begun a massive program of building highways for the residents of the suburbs can quickly get to work in the city and return home in the evening. After

World War II the millions veterans received preferential government loans for house purchase in the incredibly long term (30 years). As a result, in the coming decades the infrastructure of cities and suburbs in the United States has developed in such way that for the Americans without a car it was extremely difficult to get to work or to the shops.

Now oil is an essential part of the functioning and development of the US economy. Its share is 40% of the total energy. Oil provide 94% of the energy used in transport and 40% of the energy used in the industrial sector. The US government is concerned about dependence on foreign oil since the late 1940s, when the country became a net importer of oil.

US imports of oil has grown over the decades, reaching a peak in 2005. From 2005 to 2011 the net oil imports decreased by 33% and amounted to 8,400,000 barrels per day (Fig. 2.1). In 2011 the import of crude oil amounted to 45% of its total domestic consumption, which is 15% less compared to 60% in 2005. Since 2005, policies to stimulate consumption of biofuels has led to decline in oil imports. Having conducted analysis, the Renewable Fuels Association found that in 2011 ethanol production replaced the gasoline produced from more than 485 million barrels of imported oil.

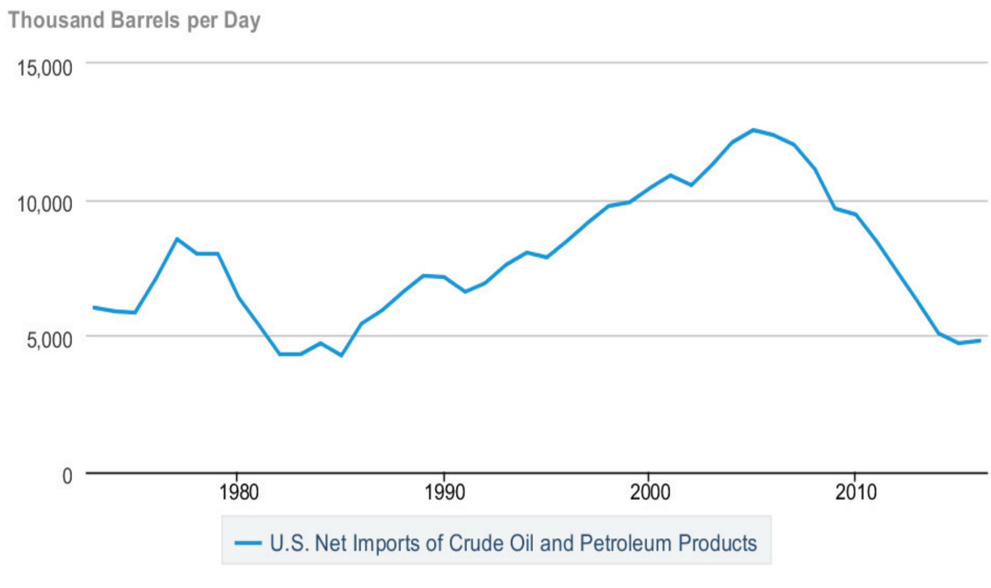


Figure 2.1. The U.S. Net Imports of Crude Oil and Petroleum Products

More than two-thirds of the gasoline demand is used by the transport sector. The US dependence on imported energy carriers leads to the risk of the trade deficit, no-rhythm supply and fluctuations in gasoline prices.

The cost of gasoline in the US (Fig. 2.2) has a clear upward trend, with the exception of 2008 due to unfavorable economic conditions, which led to lower demand for gasoline and reduce its cost. The process of restoring the world economy and the US economy prompted increased demand and energy prices therefore.

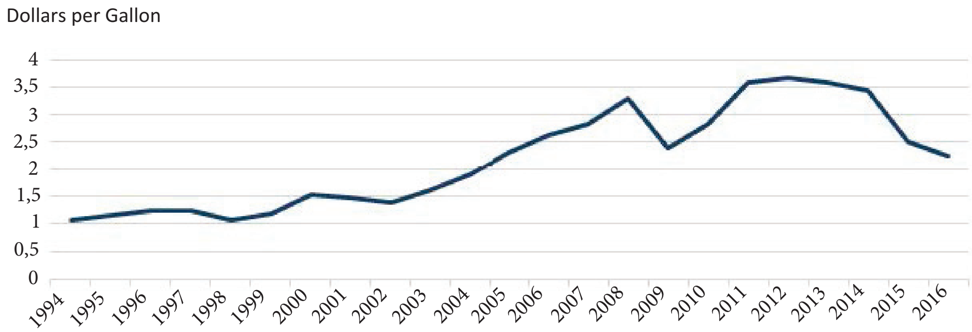


Figure 2.2 Retail Gasoline Prices in the US

The first legislative act of the US, which refers to the environment and alternative fuels become Clean Air Act, passed in 1970. It identified the US Agency of the Environmental Protection responsible for protecting and improving air quality. This Act authorized the development of various federal and local regulations to limit fuel consumption, obliged to inform consumers about the possibility of saving fuel and reducing emissions.

In 1978, the US Congress passed Public Utilities Regulatory Policies Act that aims to promote the development of the industry's alternative energy. The law obliges local utilities to buy energy from small local producers. The event was useful for the rapid construction of low-power stations, especially those working on renewable energy sources.

In 1980, President Ronald Reagan decided that the private sector can be effective in funding developments in the field of alternative energy sources. Government programs that aimed to support these research areas have been significantly reduced. Administration of President George Bush continued the policy of reducing state involvement in regulating processes in the energy market.

Alternative Motor Fuels Act was passed in 1988. It encouraged the producers of biofuels by providing preferential loans to produce cars that can run on some form of alternative fuel.

Aiming to reduce dependence on imported oil, the US Congress adopted Energy Policy Act, which included reducing the US dependence on foreign energy suppliers. However, the priority sector of energy, still had the traditional energy using oil and gas as well as nuclear energy. Clinton administration concentrated on public participation in regulating the energy market again, in particular focusing on the environmental aspects of energy use. Attention to the use of alternative energy intensified after signing the Kyoto Protocol in 1998, intended to reduce emissions of gases that cause the greenhouse effect.

However, in 2001 after the President George Bush's appearance in the White House, the US focused on the use of traditional energy sources and refused to participate in the implementation of the Kyoto Protocol.

In 2005, the US Congress passed Energy Policy Act 2005, which supposed the use of 15 billion liters of biofuels, starting in 2006. By 2012, the volume of biofuels as part of normal consumption, according to the law, had to rise to 28 billion liters. The law also envisaged the introduction of tax incentives for production and consumption of biofuels. It was planned to spend the funds in the amount of $ 4.5 billion for energy efficiency measures and improve energy efficiency.

The standard for renewable fuels (Renewable Fuel Standard, RFS) came into force in 2007 with the adoption by Congress of the Law "On Energy Indepen-

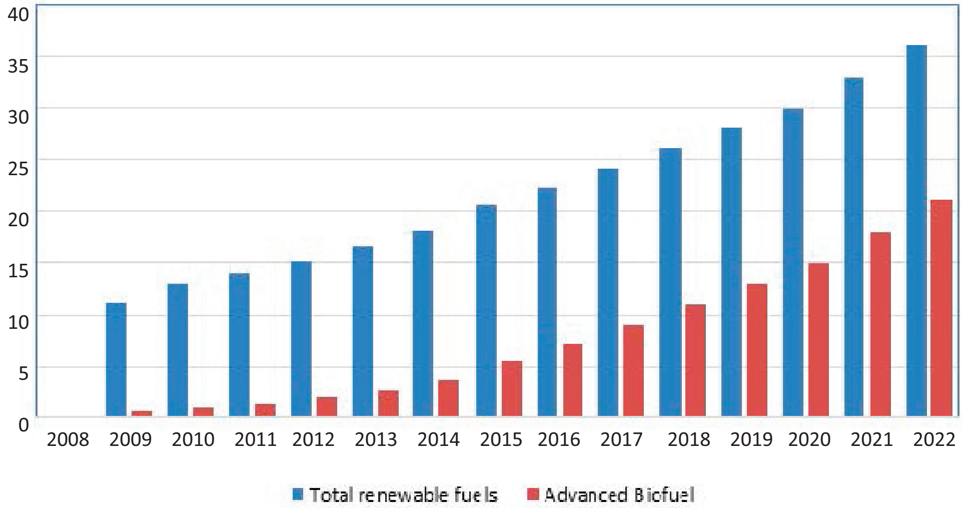


Figure 2.3. The Volume of Biofuel Production in Accordance with RFS

dence and Security" (Energy Independence and Security Act, 2007). According to it, the volume of using the first and second generation biofuel was set by 2022 .

Fig. 2.3 shows the perspective of action of the RFS standard, that established the use of 9 billion gallons of renewable fuels by 2008, 20.5 billion gallons – up to 2015 and 36 billion gallons by 2022 (1 gallon = 3.785 liters). This standard regulates the production of the second generation biofuels.

In 2009 the US Government adopted The American Recovery and Reinvestment Act. Act allocated more than 800 billion USD to create jobs, increase economic growth, reduce the tax burden, improve the education, health, infrastructure, invest in energy independence and technologies, renewable energy.

Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act adopted in 2010, extends and renews a number of alternative tax credits for biofuels.

In 2012, the American Taxpayer Relief Act that expands and renews few incentives for alternative fuels was adopted. It provides the granting of the tax credit in the amount of $ 1 per gallon of biodiesel. There remains also the tax credit in the amount of $ 1.01 per 1 gallon of cellulosic ethanol. The tax credit for ethanol produced from corn, is provided at the rate of 0.45 cents per gallon.

The USA does not plan to abandon the gradual transition to biofuels. However, the country's government is trying to replace a corn as the main feedstock for ethanol production for alternative non-food crops or waste products for the production of the second generation biofuels.

The US government recognizes the importance of biofuels, because it not only helps to reduce dependence on imported oil and reduce CO_2 emissions, but also create jobs in rural areas, where employment is very necessary. According to the Renewable Fuels Association, in 2011 ethanol production provided more than 400,000 jobs across the country, added 42.4 billion dollars of gross domestic product and increased income of the population by 29.9 billion dollars.

2.3. Legal Regulation of Biofuel Production in Brazil

Brazil is the world's second largest producer of bioethanol. Brazil is the world's largest sugarcane ethanol producer and a pioneer in using ethanol as a motor fuel. And its current volume of production and consumption has been achieved owing to favorable government policies Brazil was the world's leading fuel ethanol producer until 2005. In 2015/16, Brazilian ethanol production reached 30.23 billion litres (8 billion gallons). Most of this production is consumed by the domestic market where it is sold as either pure ethanol fuel or blended with gasoline at levels between 18 to 27.5 percent ethanol.

Almost 45% of primary energy demand is met by renewable energy, making Brazil's energy sector one of the least carbon-intensive in the world.

In 1933, the Getúlio Vargas Administration created the Sugar and Alcohol Institute (IAA) and passed Law 737, a fuel content law requiring the addition of ethanol to gasoline.

Ethanol fuel production peaked during World War II and, as German submarine attacks threatened oil supplies, the mandatory blend became as high as 50% in 1943. After the end of the war cheap oil caused gasoline to prevail, and ethanol blends were only used sporadically, mostly to take advantage of sugar surpluses, until the seventies, when the first oil crisis resulted in gasoline shortages and awareness of the dangers of oil dependence.

As a response to this crisis, the Brazilian government began promoting bioethanol as a fuel. The National Alcohol Program – Pró-Álcool, launched in 1975, was a nationwide program financed by the government to phase out automobile fuels derived from fossil fuels, such as gasoline, in favor of ethanol produced from sugar cane.

In 1975 the program acquired the status of law after it was signed by President Ernesto Heyzelem. It supported the establishment of effective national ethanol production, which was based on a system of state subsidies and tax incentives for manufacturers and owners of sugar cane processing plants. The program set a goal to produce 3.5 billion liters of ethanol by the year 1980.

The first phase of the program concentrated on production of anhydrous ethanol for blending with gasoline. The Brazilian government made mandatory the blending of ethanol fuel with gasoline, fluctuating from 1976 until 1992 between 10% to 22%.

A federal law was passed in October 1993 establishing a mandatory blend of 22% anhydrous ethanol in the entire country. This law also authorized the Executive to set different percentages of ethanol within pre-established boundaries; and since 2003 these limits were fixed at a maximum of 25% and a minimum of 20% by volume.

Thus the Brazilian Government sets the percentage on the ethanol blend according to the results of the sugarcane harvest and the levels of ethanol production from sugarcane, resulting blend variations even within the same year.

Today the statutory mandatory ethanol content in gasoline is 23%, biodiesel in diesel fuel – 5%.

The Brazilian government provided three important initial motivators for the ethanol industry: guaranteed purchases by the state-owned oil company Petrobras, low-interest loans for agro-industrial ethanol firms, and fixed gasoline and ethanol prices where hydrous ethanol was sold for 59% of the government-set gasoline price at the pump.

Subsidising ethanol production in this manner and setting an artificially low price made ethanol an alternative to gasoline.

In addition to the successful implementation of the program for the production of bioethanol the government supports biodiesel production. Federal Law No. 11097/2005 defined and established a legal mandate for the use of biodiesel as a fuel. The law authorized the use of a two percent blend of biodiesel (B2) until 2008 when B2 became compulsory nationwide, i.e., all mineral diesel must have a two percent biodiesel blend. The Brazilian legislation had also foreseen the increase of the mandatory blend to five percent (B5) by 2013.

The Brazilian government has assumed a major role in the organization of the production chain of biodiesel production, providing loans and financial incentives for the participants of the production process. Now Brazil has the second position in the structure of the production of biodiesel (fig.2.4).

Although historically Brazil's experience in the field of biofuels can be considered largely as a reaction to the rise in oil prices, the result of such favor-

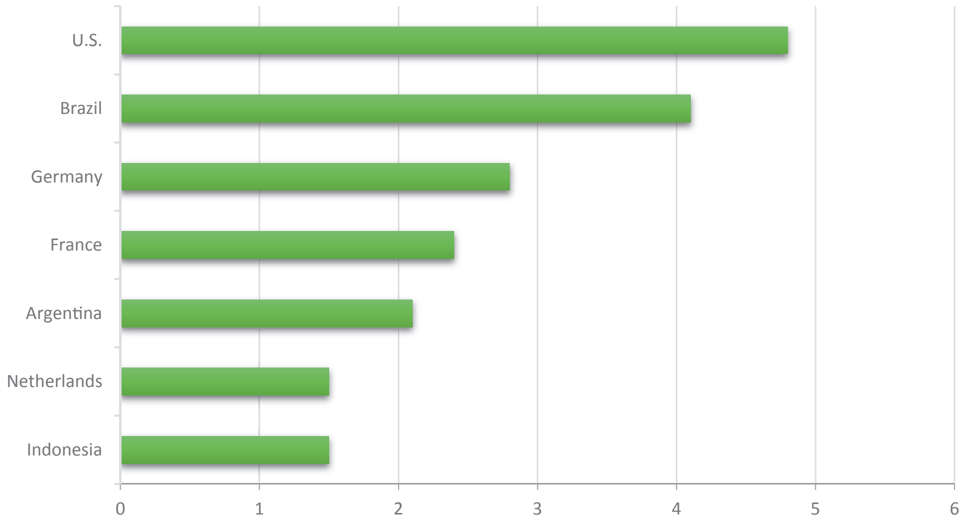


Figure 2.4 The World's Biggest Biodiesel Producers in 2015 by country (in billion liters)

able policies to overcome the country's dependency on oil country, however, it demonstrates the intention to produce more biofuels. The Brazilian Government recognizes that the positive economic effects may occur as a result of an ambitious policy in the field of biofuels by strengthening energy and environmental security and the promotion of socio-economic programs

2.4. Legal Regulation of the Market of Biofuels in the European Union

EU biofuel issue defines the main strategy for the Europeans – ecology con-servation to combat global warming on the planet which is largely based on the refusal of oil and gas and switch to newer renewable fuel. Now the European Community is largely dependent on energy supplies. Since the time of the oil crises of the 70s the EU countries have recognized the dangers of dependence on limited energy supplies. Accordingly, at Community level, measures were taken in order to diversify sources of supply and the formation of energy reserves. The integration process in Europe was ini-tially linked to energy, in particular, with its coal industry. However, with the emerge of cheap oil and natural gas in ensuring Europe's energy needs coal usage has decreased significantly. Therefore, it was very liberal in the field of energy regulation before the first oil crisis in 1973. The oil crisis in 1973 started an active intervention of the Community Energy Regulation, in particular its oil industry. The second oil crisis led to the further development and adoption of anti-crisis measures at the level of EU, aimed at energy saving, diversification of energy supply sources and the orientation of energy policy for the use of renewable energy sources and more efficient use of existing energy reserves.

Over time, the issue of diversification has given the way to the environmental concerns associated with the danger of greenhouse gases and pollution emis-sions of carbon dioxide. Nevertheless, the issue of regular energy supply and diversification of energy sources is still relevant to the EU. This aspect includes two main components: a geographical and operational. The need for geographical diversification acutely felt during the oil crises. Therefore, the main efforts of the EU are in this focus on reducing dependence on external sources of energy, especially of oil and gas. The second component concerns energy requiring connection to the shared network, namely electricity and gas. Therefore, since the early 90-ies the Community has begun to introduce of complex measures in this area.

In 2000, the EU Commission issued for public discussion the Green Paper Towards a European strategy for the security of energy supply COM (2000) 769 final) (hereinafter – the Green Paper), with main focus on ensuring regular supply of energy at affordable prices for both private and industrial consumers at the same time ensuring the necessary level of environmental protection.

The main idea of the proposed policy is not to achieve energy self-sufficiency and reduce dependence on external supplies, but above all, to minimize the risks associated with such dependence. Green Paper indicates various energy sources diversification, both geographi-cally and by type of energy source as sne of the main priorities in this area. This diversification also must meet, according to the Commission, the EU international commitments, taken under the Kyoto Protocol to the Framework Convention of the United Nations on climate change from 11 December 1997.

With the signing of the Kyoto Protocol, the advanced policy goals of Brussels are to reduce carbon emissions into the air by 35% by 2011 and by 50% by 2017 compared with 1990.

The Green Paper proposed for discussion the following areas of Community energy policy, which should be, according to the Commission, the basis of long-term EU strategy on energy:

- reorientation of policies with a view to creating the demand, not the supply;
- in the field of demand management Green Paper calls for a significant change in consumer behavior. She notes the effectiveness of the use of tax measures for demand management in order to provide a more controlled consumption which must comply with environmental requirements. The Green Paper proposes tax and parafiscal measures which would establish responsibility for the harmful effects of energy on the environment. Such measures will make the transport sector and industry introduce an active policy of energy saving and diversification in favor of energy sources that do not harm the environment;
- in the field of supply management, The Green Paper recognizes the fight against global warming as the priority. Key factor in this respect is the development of new and renewable energy sources, particularly biofuels.

At the summit in Barcelona, the European Council stressed the need for better energy efficiency and the rapid adoption of the Commission's proposals on the taxation of energy, providing, thus, political support for the Commission's proposals in this area. Even before the completion of the discussion of the Green Paper, the Commission has developed a number of important proposals in the field of energy policy of the Community. In particular, submitted the following projects to the Council:

– Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market;

– Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings;

Directve 2003/30/EC of the European Parliamtnt and Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport, Official Journal/L 123/42, 17.5.2003;

– Directive 92/81/EEC with regard to the possibility of applying a reduced rate of excise duty on certain mineral oils containing biofuels and on biofuels.

Special attention was paid to the transport sector that consumes up to 32% of the total energy consumption, and which accounts for 28% of all $C0_2$ emissions.

The 2001 Gothenburg Summit developed the Community strategy in the field of energy policy. In particular, a separate part of the strategy is dedicated to climate change and increase in the use of clean energy. In this part, the Commission pointed to the adoption of such measures as:

- in the international arena, to meet commitments under the Kyoto Protocol the EU will seek to reduce annual emissions of gases that cause the greenhouse effect, to 2020 to 1% of the level that existed in 1990;
- the EU will direct its efforts on the international stage to ensure that other major industrialized nations comply with their obligations under the Kyoto Protocol;
- at the level of the European Community: the adoption of the Directive on the taxation of energy derived from alternative sources (2002). For two years thereafter, the EU announced its intention to offer even more ambitious measures in the field of taxation of energy aimed at ensuring the protection of the environment in order to complete the transfer of external costs of economic entities, as well as indexation of minimum levels of excise duty, at least in accordance with inflation;
- phasing out subsidies solid for fuel production and consumption in 2010. This was accompanied by measures to support the creation of new jobs;
- taking measures to reduce emissions of gases that cause the greenhouse effect, which will be developed according to the results of the European program on climate change;
- implementation of measures in support of the production of alternative fuels, including biological, in order to bring the level of consumption of vehicles up to 7% as of 2010 and at least 20% in 2020;

• provide more support for research, development and dissemination of technology on clean and renewable energy and safer nuclear energy, particularly in the management of nuclear waste.

In this case, the EU Commission proposed to adopt the Directive on the promotion of biofuels for transport and Directive amending Directive 92/81/EEC in order to introduce the possibility of applying reduced rates of excise duty on certain mineral oils containing biofuels and on biofuels.

The first legal document that regulated the mandatory biofuel content in the conventional fuels in the EU was Directive on the promotion of the use of biofuels and other renewable fuels for transport, the official name of that was Directive 2003/30/EC.

This legislation entered into force in May 2003 and involved the adoption of national measures in the EU, aimed at replacing 5.75% of all transport fossil fuels (petrol and diesel) for biofuels by 2010.

The Directive also dealt with the achievement of the intermediate target in the amount of 2% of biofuels until 31 December 2005. According to the Directive, the share of biofuel in the amount of 5.75% had to be achieved by 31 December 2010.

Now the production of biofuels in the EU is regulated by the EU package on energy and climate change (The EU Energy and Climate Change Package).

The main regulatory instrument in this package was a Directive on renewable energy (Renewable Energy Directive 2009/28/EG), which entered into force on 25 June, 2009 and has been adapted to the national legislation of EU member states.

All member states were also obliged to submit before June 30, the Nation-al Action Plans for Renewable Energy. The Directive provides the defini-tion of mandatory national targets for the portion of the energy produced from renewable sources in the total final energy consumption and the portion of the energy produced from renewable sources for its consumption in the transport sector.

EU package on energy and climate change targets provides “20/20/20” to 2020. It is expected to reduce greenhouse gas emissions by 20% compared with 1990, a 20% increase in energy efficiency by 2020, compared with the previous set indicators. At the same time 20% of energy should come from renewable sources, 10% of which comes from transport.

Mandatory national objectives aimed to provide some assurance to investors and to encourage a long-term technology development, by making use of the energy which is produced from all types of renewable sources.

National renewable energy action plans to set national targets for energy share to the Member States, produced from renewable sources and consumed in the transport sector and in electricity production, heating and cooling up to 2020, taking into account the effects of other events, related to energy efficiency of final energy consumption. They give a description of the measures to be taken in order to achieve national global goals, in particular the cooperation between local, regional and national authorities, provided for statistical transfers or joint projects, the development of national strategies for the development of biomass resources for different uses.

No later than 31 December 2011 and thereafter every two years, the state – members of the EU sould submit a report on the progress made in the promotion and use of energy from renewable sources. The sixth report, which will be submitted not later than 31 December 2021 should be the last report that is required.

Global objectives of the Member States on the share of energy produced from renewable energy sources, as of the energy consumption by the end of 2020-year are shown in table 2.1.

Table 2.1

Global Objectives of the Member States on the Share of Renewable Energy by 2020

Country	The share of energy extracted from renewable sources in the total final energy consumption in 2005, %	The purpose of the private energy produced from renewable energy sources in the total final energy consumption in 2020, %
France	10,3	23
Germany	5,8	18
Denmark	17,0	30
Latvia	32,6	40
Austria	23,3	34
Portugal	20,5	31
Finland	28,5	38
Sweden	39,8	49

Member States significantly increase the level of energy efficiency in all sec-tors in order to achieve more easily the goals envisaged for them in the area of bio-energy (insulation, windows replacement, boiler, energy-saving technolo-gies, the prudent use of energy).

Member States, with the participation of local and regional authorities, shall develop suitable information, awareness-raising, guidance or training programmes in order to inform citizens of the benefits and practicalities of developing and using energy from renewable sources

It is desirable that energy prices reflect external costs of energy production and consumption, including, as appropriate, environmental, social and health-care costs.

Public support is necessary to reach the Community's objectives with regard to the expansion of electricity produced from renewable energy sources, in particular for as long as electricity prices in the internal market do not reflect the full environmental and social costs and benefits of energy sources used.

The Community and the Member States should strive to reduce total consumption of energy in transport and increase energy efficiency in transport. The principal means of reducing consumption of energy in transport include transport planning, support for public transport, increasing the share of electric cars in production and car industries which are more energy efficient and lower both in size and in engine capacity

According to the Directive (2009/28/EG), biofuels have also been complied with the sustainability criteria. Since the production of feedstock for processing into biofuels CO_2 emissions should be minimal, and the feedstock used for biofuel production – to answer the sustainability criteria.

Biofuels and bioliquids shall not be made from feedstock coming from land with high biodiversity value, namely land that had one of the following statuses in or after January 2008, whether or not the land continues to have that status:

(a) primary forest and other wooded land, where there is no clearly visible indication of human activity and the ecological processes are not significantly disturbed;

(b) areas designated by law or by the relevant competent authority for nature protection purposes; or for the protection of rare, threatened or endangered ecosystems or species recognised by international agreements or included in lists drawn up by intergovernmental organisations or the International Union for the Conservation of Nature; unless evidence is provided that the production of that raw material did not interfere with those nature protection purposes;

(c) highly biodiverse grassland that is natural, namely grassland that would remain grassland in the absence of human intervention and which maintains the natural species composition and ecological characteristics and processes; or non-natural, namely grassland that would cease to be grassland in the absence of human intervention and which is species-rich and not degraded, unless evidence is provided that the harvesting of the raw material is necessary to preserve its grassland status.

Biofuels and bioliquids shall not be made from feedstock obtained from land with high carbon stock, namely land that had one of the following statuses in January 2008 and no longer has that status:

(a) wetlands, namely land that is covered with or saturated by water permanently or for a significant part of the year;

(b) continuously forested areas, namely land spanning more than one hectare with trees higher than five metres and a canopy cover of more than 30 %, or trees able to reach those thresholds in situ;

(c) land spanning more than one hectare with trees higher than five metres and a canopy cover of between 10 % and 30 %, or trees able to reach those thresholds, unless evidence is provided that the carbon stock of the area before and after conversion is such that, when the methodology laid down is applied. The provisions of this paragraph shall not apply if, at the time the raw material was obtained, the land had the same status as it had in January 2008.

Biofuels and bioliquids shall not be made from feedstock obtained from land that was peatland in January 2008, unless evidence is provided that the cultivation and harvesting of that feedstock does not involve drainage of previously undrained soil.

From 1 January 2017, the greenhouse gas emission saving from the use of biofuels and bioliquids shall be at least 50 %. From 1 January 2018 the greenhouse gas emission saving shall be at least 60 % for biofuels and bioliquids produced in installations in which production started on or after 1 January 2017.

By introducing new biofuel technology, the European Union aims to overcome the dependence on imported oil, to prevent global climate change obligations under the Kyoto Protocol and support the development of agriculture. Biofuels production in all EU countries depend on the state intervention. The biofuls production stimulation policies depend on the capabilities of the country.

2.5 Regulatory Framework for Production and Use of Alternative Energy Sources in Ukraine

In the area of traditional energy sources, there is a number of laws and other legal documents that define the legal relations in this field, terms and their interpretations, methods for determining the performance of different energy sources and more.

At the state level it has been adopted legislation and regulations aimed at promoting production and consumption of biofuels in Ukraine:

1. Decree of the President of Ukraine "On the Construction of Wind Power Plants" on 2 March, 1996 provides approving the State program of construction of wind power plants by Cabinet Ministers of Ukraine until 31 December 1996 to take measures to attract investments for the construction of wind power plants and production of modern wind power equipment by Ministry of mechanical engineering and military-industrial complex and conversion of Ukraine with the participation of the Ministry of Economy of Ukraine, State Property Fund of Ukraine and the Antimonopoly Committee of Ukraine.

2. Decree of the President of Ukraine "On Urgent Measures to Ensure Ukraine Energy Sources and Their Rational Use" of March 22, 1997 provides for six months to prepare a program for the development of alternative and renewable energy and small hydro and thermal power as part of the National Energy Program of Ukraine.

3. The Cabinet of Ministers of Ukraine "On State Support of Alternative and Renewable Energy and Small Hydro and Thermal Power" of December 31, 1997 determined: 1. To approve the program for the development of alternative and renewable energy and small hydro and thermal power as part of the National energy program of Ukraine. 2. National Agency for Efficient Use of Energy Resources to coordinate work, monitoring their implementation, synthesis materials to implement the program and annually by April 1 to inform the Cabinet of Ministers of Ukraine on the progress of its implementation

4. The Law of Ukraine "On Alternative Fuel" of 14 January 2000 defines the legal, social, economic, environmental and organizational principles of production, extraction and consumption of alternative types of liquid and gaseous fuels from alternative sources and types of energy resources, aimed at creating the necessary conditions for the expansion of production and consumption of these fuels in Ukraine. There are certain legal gradual increase share of production and use of biofuels and blended motor fuels. The recommended content of ethanol in motor gasoline produced and/or sold in Ukraine will be the following: in 2013 – recommended content of not less than 5%; in the 2014-2015 the mandatory content of not less than 5%; 2016 – mandatory content of not less than 7%. It has been prohibited the storage and transportation of ethanol without denaturation on with 1-10% gasoline.

5. By the Resolution of the Cabinet of Ministers of Ukraine №1044 "On Approval of the Program "Ethanol" dated on 4 July 2000 it has been envisaged to expand the use of ethanol as an energy source and raw material for industry. The main directions of the program are the production of high-octane oxygen-containing additives to the gasoline, ethyl tert-butyl ether, ethylene,

acetone, synthetic rubber, biodiesel. The aim of the Programme is to create favorable conditions for the production of products using biological renewable raw materials and energy, as well as the organization of new to Ukraine and reorientation of existing production on the use of replacement products processing agricultural feedstock, namely ethyl alcohol and its derivatives. (The resolution has expired on the basis of the Resolution of the Cabinet of Ministers of Ukraine dated January 5, 2011)

6. Law of Ukraine "On Alternative Energy Sources" on 20 January, 2003 sets out the legal, economic, environmental, and organizational principles for the use of alternative energy sources, its provisions are aimed at promoting the expansion of their use in the energy sector. According to the Law, the basic principles of state policy in the field of alternative energy sources are increasing the volume of production and consumption of energy produced from alternative sources; compliance with environmental safety by reducing the negative impact on the environment during construction and operation of the alternative energy, compliance with sustainable consumption and saving of energy produced from alternative sources; attracting domestic and foreign investment and support for entrepreneurship in the field of alternative energy sources, including the development and implementation of national and local programs for the development of alternative energy, scientific and technical support for alternative energy development, promotion and implementation of scientific and technological achievements in this field, the preparation of the relevant specialists in higher and secondary educational institutions.

7. Decree of the President "On Measures to Develop the Production of Fuel on Biological Raw Material" on 26 September 2003 has been adopted to reduce the dependence of the national economy on the import of petroleum products, development of agriculture, improvement of the ecological situation and taking into account the European Parliament Directive 2003/30/EC and of the Council on 8 May 2003 on the promotion the use of biological and other fuels derived from renewable resources. Proving the production and increased use of fuel from biological raw material is one of the priority directions of activity of the Cabinet of Ministers of Ukraine, central and local enforcement authorities. According to the Decree, it is necessary to perform a number of activities: the Cabinet of Ministers of Ukraine to develop and adopt before 1 January 2005 the program of development of production of biodiesel and biogas for the period until 2010; ensure the mandatory use of high-octane oxygen additive to gasoline in the production of motor gasoline mixed with a gradual, until 2007, bringing its content in these gasolines up to 5%; introduce economic mecha-

nisms to stimulate the production of machines, appliances, power plants and other technical means, working on fuel from biological feedstock, and their use in industry, energy, transport; ensure the harmonization of national legislation in the sphere of production and use of fuels from renewable raw materials with EU legislation; provide coverage in the media activities undertaken to produce fuel from biological raw material development.

8. Resolution of the Cabinet of Ministers of Ukraine "On the Order of Issuance of the Fuel Supplies to the Alternative" on 5 October 2004 provided that a certificate of affiliation to the alternative fuel is issued by the State Agency on Energy Efficiency and Energy Conservation in the following order: 1. The interested person shall submit a request for grant evidence and expert opinion on the presence of signs of alternative fuel to the Agency. The examination procedure to confirm the fuel supplies to the alternative is determined by the Ministry.
2. The Agency shall consider the application within 10 days and make a decision to grant a certificate or refusal to issue it and shall notify the applicant in writing with a justification reasons for refusal. The certificate is valid for two years in the form according to the appendix. In case of loss of certificate of the Agency at the request of the person concerned, it is issued a duplicate.

9. Order of the State Committee of Ukraine for Energy Conservation "On Approval of the Examination to Confirm the Fuel Supplies to The Alternative" on 10 December, 2004 approved the procedure for the examination to confirm the fuel supplies to the alternative. The registry form of alternative fuels for Ukraine energy efficiency has been established. The examination of the fuel supplied by the applicant carried out to verify conformity with the fuel attributes defined in Article 3 in The Law of Ukraine "On alternative types of liquid and gas fuels" and is required for each type of fuel Technical indicators.

10. Decree of the Cabinet of Ministers of Ukraine dated March 15, 2006 No.145-r "On approval of the Energy Strategy of Ukraine till 2030" identified the following goals of the country's energy strategy in the field of alternative energy: the creation of conditions for permanent and quality meet the demand for energy products, ways to predict and creating conditions for the safe, reliable and stable operation of power and its maximum effective development, ensuring energy security, reduction of anthropogenic impact on the environment and to ensure civil protection in the field of technological safety, lowering unit costs in the production and use of energy through sustainable consumption, introduction of energy saving technologies and equipment, rationalization of the structure of social production and the decrease in the proportion of energy-intensive technology, integration of the United Energy System of Ukraine

in the European energy system and increase electricity exports, strengthening the position of Ukraine as a transit country of oil and gas.

11. Resolution of the Cabinet of Ministers of Ukraine "On the Program of Development of Biodiesel Production" on 22 December, 2006 provided to produce about 520 thousand tons of biofuels in 2010, with total financing of more than 8.9 billion USD. In support of the development of the industry of alternative non-conventional and renewable sources of energy allocated for 2007 to 15 million hryvnia, but they were not used.

12. Resolution of the Presidium of NAS Ukraine on 28 February, 2007 approved the target complex program of scientific research of the NAS of Ukraine "Biomass as a Fuel Feedstock".

13. Law of Ukraine "On the Development of Production and Consumption of Biofuels", adopted by the Verkhovna Rada of Ukraine on June 18, 2007, provided for fiscal support to the industry, regulatory support, development of the infrastructure and regions, scientific and technical and information support. (This law has not been signed by the President and has not entered into force).

14. Resolution of the Cabinet of Ministers of Ukraine "On approval of the lists of companies from all stages of the process for the production of petroleum products", with the right to produce gasoline and motor mixtures containing ethyl tert-butyl ether or additives based on bioethanol, and state distilleries eligible for bioethanol production' on December 5, 2007 approved the list of companies from all stages of the process for petroleum products manufacturing, having the right to produce gasoline motor mixed A-92 ECO, A-95 ECO, A-98 ECO with additives based on bioethanol, the content in these gasolines is from 2 volume percent, or containing ethyl tert-butyl ether from 5 percent by volume, and state distilleries eligible for bioethanol production.

15. Resolution of the Cabinet of Ministers of Ukraine "On Approval of the Concept of the State Target Scientific and Technical Program of Development of the Production and Use of Biofuels", dated February 12, 2009 N 276-P provides a program of diversification of energy sources, use of the potential of agricultural production and processing industry through the introduction and use of biotechnologies, technologies for processing organic raw materials, including household and industrial wastes. Period of the Program is 2010-2014.

16. Law of Ukraine "On Amendments to Some Laws of Ukraine on Facilitating the Production and Use of Biofuels" from May 21, 2009 decided to stimulate the production and use of biofuels, the development of Ukrainian national fuel from biomass attracting the market as a renewable raw material for the production of biofuels. According to the law, the excise rate is set 0

hryvnia per 1 liter of bioethanol. The tax bill issued prior to the production of bioethanol producers for the production of mixed motor fuel, avalized by bank, in the amount of excise duty charged on the amount of ethanol produced, based on the rate, which is defined as the difference between the full rate of excise duty on ethyl alcohol, provided by applicable law and the rate of 0 hryvnia for 1 liter of 100 percent alcohol. Temporarily, for a period of 10 years starting from January 1, 2010 biofuel producers shall be exempt from taxation income derived from the sale of biofuels. Temporarily, until January 1, 2019, there is no taxation on transactions for import of goods, machinery and equipment used for the reconstruction of existing and con-struction of new plants for the production of biofuels and for the production and reconstruction of technical and vehicles to biofuels, if such goods are not produced and have no analogues in Ukraine.

17. Resolution of the Cabinet of Ministers of Ukraine "On Approval of the Customs Territory of Ukraine the Order of Import of Machinery, Equipment, Technology and Vehicles Used for the Development Of Production and Ensure the Consumption of Biofuels" on May 18, 2011 defined the mechanism of economic entities of the importation into the customs territory of Ukraine without paying import duties and value added tax, equipment used for the reconstruction of existing and construction of new plants for the production of biofuels, manufacturing and reconstruction (conversion) technology and vehicles to ensure consumption of biofuels, industrial and vehicles, including self-operated agricultural machinery, working with biofuels.

18. Law of Ukraine "On Amendments to the Law of Ukraine On Electric Power Industry to Promote the Use Alternative Sources of Energy" on November 20, 2012 provides incentives to increase the share of alternative fuels to 20% of total fuel consumption in Ukraine until 2020 Green Tariff – a special tariff for purchase of electricity generated at energy facilities that use alternative energy sources (except for blast furnace and coking gases, and using hydropower – only produced in small hydropower plants). The wholesale mar-ket of electric energy of Ukraine obligations related to buy-on-green tariff for electricity produced at power generation facilities that use alternative energy sources. The law defines the following green tariff rates for electricity generated using alternative energy sources (Table 2.2).

In Ukraine, the total annual technically achievable energy potential of alternative energy sources in terms of conventional fuel is about 63 million tons. The share of energy produced from alternative sources, is about 3% today. According to the Ukrainian energy strategy until 2030, the share of alternative energy in the overall energy balance of the country will be 20% (Table 2.3). The main and most effective types of renewable energy in Ukraine are wind power, solar power, bioenergy, hydropower, geothermal energy.

Table 2.2

The Coefficients of "Green" Tariff for Electricity Generated Using Alternative Sources of Energy

Categories of power facilities, which use "green" tariff	Until 31. 03.2013	01.04.2013 – 31.12.2014	01.01.2015 – 31.12.2019	01.01.2020 – 31.12.2024	01.01.2025 – 31.12.2029
For electricity generated from wind energy by wind power plants with capacity not exceeding 600 kW	-	1.2	1.08	0.96	0.84
For electricity generated from wind energy by wind power plants with capacity from 600 to 2000 kW	-	1.4	1.26	1.12	0.98
For generated from wind energy by wind power plants with capacity of more than 2000 kW	-	2.1	1.89	1.68	1.47
For electricity generated from biomass	2.3	2.3	2.07	1.84	1.61
For electricity generated from biogas	-	2.3	2.07	1.84	1.61
For electricity generated from solar energy by ground electric power facilities	4.8	3.5	3.15	2.8	2.45
For electricity generated by micro hydropower	1.2	2.0	1.8	1.6	1.4
For electricity generated by small hydropower stations	1.2	1.2	1.08	0.96	0.84

According to expert estimates, the potential of our country allows to produce alternative energy sources until 2020 in such volumes:

- Bioethanol – about 7 million tons;
- Biodiesel – about 6 million tons;
- biogas – about 10 billion m^3;
- heat from boilers on biomass – about 8 million s.f.

In the area of alternative energy sources, there are national standards that establish:

Table 2.3

Projected Rates of Use of Alternative and Renewable Energy Sources in Key Areas of Development, in millions of s. f. per year

Indicators	The level of ARES			
	2005	2010	2020	2030
Off-balance energy sources, overall	13.85	15.96	18.5	22.2
including mine methane	0.05	0.96	2.8	5.8
Renewable energy, total, including	1.661	3.842	12.054	35.53
Bioenergy	1.3	2.7	6.3	9.2
Solar power	0.003	0.032	0.284	1.1
Small hydropower	0.12	0.52	0.85	1.13
Geothermal energy	0.02	0.08	0.19	0.7
Wind	0.018	0.21	0.53	0.7
Energy environment	0.2	0.3	3.9	22.7
Total	15.51	19.83	30.55	57.73

- basic requirements for alternative energy sources, their purpose, scope and classification and use;
- classification of power plants that use alternative sources of energy;
- basic requirements for regulations on the use of alternative energy sources;
- definitions in the field of alternative energy and secondary energy sources;
- range of performance efficiency indicators of power plants that use alternative sources of energy.

Now, many factors contribute to the production and use of biofuels. However, its production and consumption should be organized with the support of the state. Governments around the world provide legal regulation in this sphere, and then develope methods to stimulate and promote the production and consumption of biofuels. For the successful implementation government should analyze the achievements of the leading countries in this field and focus on the effective implementation of state regulation methods and stimulation of the process.

In general, laws of Ukraine help to create an appropriate legal framework governing the scope of the use of biofuels. The issue is to ensure the effec-tive implementation of the adopted legislation. Ukrainian government has to identify the legal responsibilities for failure in adding the needed amount of biofuel and rules to tighten control over the implementation of the current legislation.

Basic definitions and concepts. *Convention. Kyoto Protocol. Ratification. Climate change. Reducing emissions. Energy saving. Energy-saving technology. Diversification. Quotas. Legislation. State Strategy. USA. Brazil. State policy. Government subsidies. Tax credits. Stimulation. State program. Fixed prices. The fines. Directive. National goals. State standards.*

Test questions and tasks

1. What are the reasons for the organizations to initiate the development of "Framework Convention on Climate Change"?
2. What are the main requirements of the Kyoto Protocol?
3. What are the countries that have signed and ratified the Kyoto Protocol obliged to do?
4. What are the obligations of Ukraine under the Kyoto Protocol?
5. Which countries have not ratified the Kyoto Protocol requirements?
6. How can Ukraine direct the funds received from the sale of emission allowances in accordance with the requirements of the Kyoto Protocol?
7. What are the main goals of the US energy policy?
8. When was the first law in the United States on environmental protection and the development of alternative fuels adapted?
9. What are the directions of regulations in the sphere of production and consumption of alternative fuels in the US?
10. Describe the features of the regulatory regulated production of biofuel in Brazil.
11. What are the main goals of EU policy since signing of the Kyoto Protocol?
12. What are the legal documents that regulate the production and consumption of biofuels in the EU?
13. Who sets the objectives of the EU Member States to raise the share of energy?
14. What criteria must the feedstock that is used for biofuel production meet?
15. Describe the basic legislative and normative acts in the field of alternative energy in Ukraine.
16. Who approves the list of companies from all stages technological process for the manufacture of petroleum products, with the right to produce motor gasoline mixtures A-92 ECO, A-95 ECO, A-98 ECO with additives based on bioethanol?

17. According to what legislation there are prohibits for storage and transportation of bioethanol without denaturtaion?
18. What is the total annual energy potential of alternative energy sources in Ukraine?
19. What kinds of power generated from renewable sources have higher coefficient of "green" tariff?
20. Do legislative acts of Ukraine contribute to establish a proper legal framework for regulation of the sphere of use of biofuels?

CHAPTER 3
EFFICIENCY OF PRODUCTION AND USE OF BIOETHANOL

Key issues

3.1. General Concepts and Aspects of Bioethanol Consumption
3.2. Feedstock for Bioethanol Production
3.3. World Experience in the Production and Use of Bioethanol
3.4. Production of Bioethanol from Sugar-Containing Feedstock
3.5. Production of Bioethanol from Starch-Containing Feedstock
3.6. Obtaining Biogas from Bioethanol Production Waste
3.7. Perspective Directions of Bioethanol Production and Use in Ukraine

3.1. General Concepts and Aspects of Bioethanol Consumption

Bioethanol is a product of carbohydrates containing materials (biomass and/or waste organic fraction) bioconversion with a regulated number of related and denaturing impurities. Bioethanol is the most common type of liquid biofuels in the world, which use as motor fuel allows to overcome energy dependence and significantly reduces environmental impact compared to traditional fossil fuels.

Bioethanol is produced by biochemical transformation of biomass or the so-called process of fermentation (fermentation) or using heat and chemicals in the thermochemical conversion. Previously, almost all ethanol obtained in this way was used for the production of alcohol and only small amounts derived by chemical methods, found application in industry. Over the past 40 years the situation has radically changed. Now only 15% of ethanol is used for the production of alcoholic beverages, the rest – as an additive to fuel for internal combustion engines.

The most common method of producing ethanol is a method of hydrolysis of polysaccharides to simple sugars (maltose – cereal starch and potato sucrose – from molasses and beet pulp and wood). On a smaller scale processes, we can use cellulose hydrolysis of hemicellulose and cellulose enzymatic hydrolysis using lignin as solid fuel for heat during the process.

The alcohol fermentation process is the process of converting the simple sugars (glucose, fructose) under the influence of enzymes to ethanol and CO_2. The overall chemical formula for alcoholic fermentation is:

$$C_2H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

In terms of molecular weight conversion, 180 kg of glucose can theoretically produce 92 kg of ethanol and 88 kg of carbon dioxide.

In general, the technology for bioethanol production consists of two stages: the production of crude alcohol and hydrated ethanol.

Describing the quality of ethanol as a motor fuel, it should be noted that it has a higher octane rating compared to petrol, it has also higher vapor pressure. However, because of the oxygen content in ethanol molecule, weight fraction of ethanol contains 33% less energy than the same weight fraction of hydrocarbons (gasoline). The possibility to use ethanol-gasoline blends containing up to 25% ethanol in their engines without additional conversion promotes using ethanol as a fuel. The environmental benefits of ethanol as a fuel are also important. As a result of incomplete combustion of gasoline, the exhausts of cars contain significant amounts of toxic gases as carbon monoxide and nitrogen. The combustion in engines of pure ethanol or added to gasoline oxygen-containing additives, which are ethanol, significantly reduces the content of carbon monoxide and other products of incomplete oxidation of the exhaust gases.

Perhaps even more substantial positive effect is biotechnologically derived ethanol as a fuel for global warming, mainly caused by additional emissions of carbon dioxide from burning fossil fuels into the atmosphere. Burning etha-nol that is derived from biomass does not cause the emission of additional CO_2 into the atmosphere since the same amount would be freed as a result of the carbon cycle, caused by microorganisms.

Ethanol has been known to mankind since ancient times. It is believed that not less than 8,000 BC people knew about the effect of fermented fruit, and later through the fermentation of fruit and honey they received alcohol drinks containing ethanol.

But beer and wine obtained by fermentation, could not contain more than 15 percent alcohol by volume, as a higher concentration in the fermentation of yeast cannot be provided. After all, it has been found that higher concentrations of ethanol can be achieved by distillation.

At the beginning of our era, distillation was well known by the Greeks and Arabs. Greek alchemists from Alexandria engaged distillation in the 1st century AD, and later the Arabs took over their experience.

In Europe, the first distillation unit was established in Italy in the 13th century by Taddeo Alderotti.

In 1386, the Genoese ambassadors brought the first aqua vitae ("the water of life") to Russia and presented to the royal court.

In 1660, the English chemist Robert Boyle was the first who discovered the ability of ethanol to be a high temperature fuel.

In 1796, the German-Russian chemist Johann Tobias Lowitz obtained pure ethanol by mixing partially purified ethanol (the alcohol-water azeotrope) with an excess of anhydrous alkali and then distilling the mixture over low heat. The French chemist Antoine Lavoisier described ethanol as a compound of carbon, hydrogen, and oxygen, and in 1807 Nicolas-Théodore de Saussure determined the chemical formula of ethanol. Fifty years later, Archibald Scott Couper published the structural formula of ethanol – $\mathbf{C_2H_5OH}$. It was one of the first determined structural formulas.

The first experiments with alcohol motor fuels were conducted in Germany and France. In 1876, Nicolas Otto, the inventor of the modern four-combustion engine, actively began to use ethanol as a fuel. In Germany the application of alcohol as motor fuels has been developed by the Higher Technical School in Berlin and Fermentation Institute in 1896-1906.

In the 1850s, the US also used ethanol as fuel for lamps, but its use declined when the alcohol started to impose a tax to pay the costs of the Civil War. The use of ethanol as a fuel recovered after the tax was abolished. Henry Ford used ethanol as a fuel for cars in 1908. To increase the octane number of gasoline, ethanol blends with gasoline were widely used in the 1920s and 1930s. These mixtures were in great demand during the Second World War due to reduction of oil supplies.

The current bioethanol production started in 1970, when the cost of fuel oil began to grow rapidly and their widespread use had a negative environmental impact.

Today bioethanol as a fuel is mainly used in transport sector. It's implemented at gas stations as mixtures with gasoline. The most fuel is marked E5, E10, E85, E100, indicating the percentage of ethanol contained in gasoline.

Since 2000, there was a clear tendency to increase the production of bioethanol. World production of fuel ethanol has increased almost 5 times during the 2000-2013. By 2022, world ethanol production is projected to increase by almost 70% (fig.3.1).

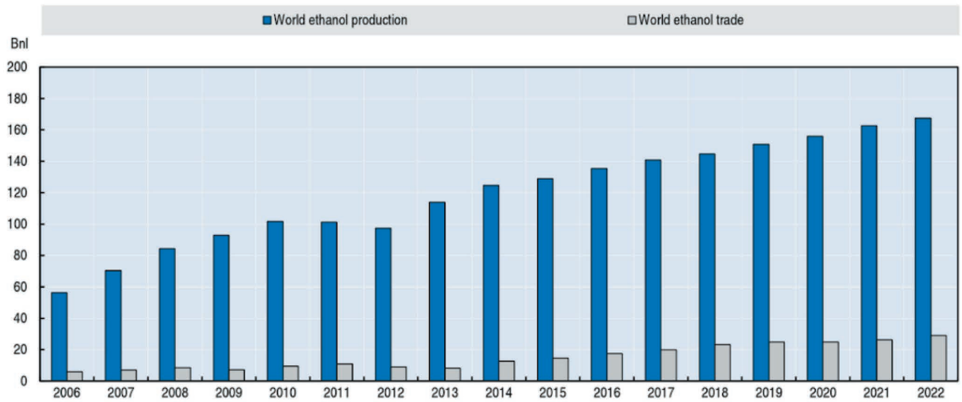


Figure 3.1. The Tendency of Bioethanol Production Increase

The three major producers are expected to remain the United States, Brazil and the European Union. In 2015, the leaders of bioethanol production were the United States, Brazil, China and the EU (fig. 3.2).

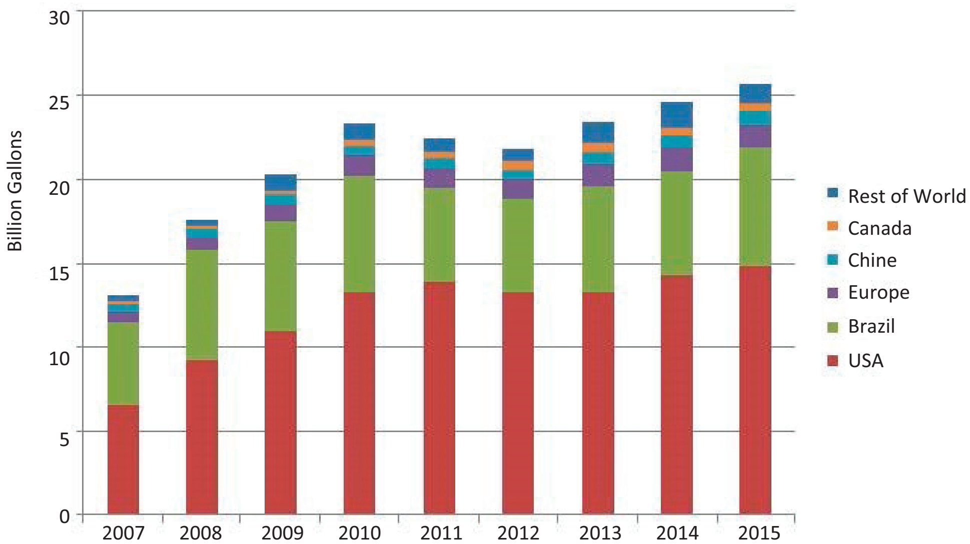


Figure 3.2. Global Ethanol Production by Country/Region and Year

In 2015, the world production of bioethanol rose by 2.7% year over year to 115.1 million m³. The fuel sector accounted for over eighty percent (97.1 million m³) of it. World leader in the production of bioethanol is the USA with 57.5 million m³, followed by Brazil with 30.0 million m³ (table 3.1 and 3.2).

Table 3.1

Fuel Ethanol Production by Main Producers (million liters)

Calendar Year	2010r	2011r	2012r	2013r	2014r	2015e	2016f	2017f
France	942	846	829	995	975	968	970	970
Germany	765	730	776	851	920	937	950	950
Hungary	190	190	291	392	456	637	640	640
Belgium	315	400	410	451	557	560	560	560
Netherlands	100	275	451	524	520	520	450	520
Spain	471	462	381	442	453	494	400	400
United Kingdom	352	89	215	278	329	253	250	250
Poland	194	167	213	235	181	214	241	253
Austria	199	216	216	223	230	235	235	235
Total	**4,268**	**4,392**	**4,658**	**5,000**	**5,250**	**5,190**	**5,050**	**5,050**
r = revised/e = estimate/f = forecast EU FAS Posts								

With 968 mln litres, France was the leading producer in Europe in 2015. However Germany is a close second with 937 mln litres. Own capacity to meet domestic demand for bioethanol in the EU is not enough, so its import amounted to 50 million decaliters in 2014. This production capacity increased four times compared to 2006 and reached 848.1 million dal.

Table 3.2

Production of bioethanol in the EU, million decaliters

Indicators	2006	2007	2008	2009	2010	2011	2012	2013	2014
Production	160.8	180.3	281.6	355.3	426.8	439.2	462	519	538
Imports	22.8	100	110.1	89.9	88	128.5	82.7	50	50
Consumption	172.5	237.5	350.9	460.3	525.3	550.6	563.3	570	576
Production capacity	206.6	345.8	513.8	623.4	757	775.9	846.8	848.1	848.1

With the increase in bioethanol production in the EU, prices on the European market reduced. Since 2012 the cost of 1 ton of ethanol amounted to 814 EUR, 2013 – 777, 2014 – 620 euros. This is generally due to lower commodity prices and growth in production volumes. In Ukraine, cost of 1 ton of ethanol was slightly lower and amounted to 703 euros/tonne in 2013.

Studies confirm that world ethanol production in 2013 provided the reduction of greenhouse gas emissions by nearly 274,000 tons per day. Compared with 2012, due to increased consumption of biofuels, the number of daily emissions decreased by nearly 4000 tonnes. The use of ethanol in gasoline in 2015 reduced CO_2-equivalent to greenhouse gas emissions from transportation by 41.2 million metric tons – equivalent to removing 8.7 million cars from the road for an entire year.

According to the data of Institute of Food Resources the country produced 15.1 decaliters of ethanol in 2013. The volume of bioethanol production was 4.06 million decaliters.

Thus, the growth in bioethanol production shows that advanced countries will develop the production and consumption. Ukraine as an energy dependent country with strong agricultural potential should as soon as possible turn to mass production and use of bioethanol.

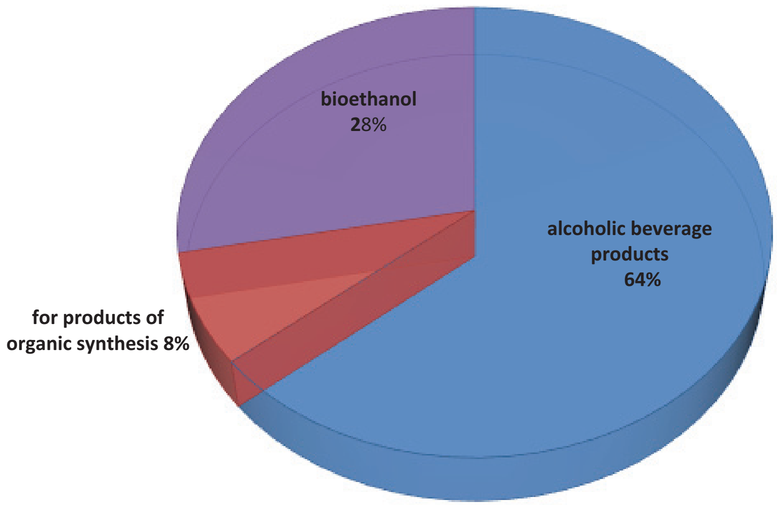


Figure 3.3 Ethanol Market Structure in Ukraine

Denaturation of bioethanol. To prevent misuse of technical ethyl its denaturation provided by various organic impurities. There are general and specific denaturation.

The Law of Ukraine "On Alternative Fuels" prohibited the storage and transport of bioethanol without denaturation of 1-10% gasoline.

Denaturing additives and their composition should provide alcohol with repulsive bad taste; be cheap and do not increase the cost of alcohol; be effective in small quantities and easily felt in denatured alcohol and its solutions; be easily determined in counterfeit drinks; be such as to remove them from alcohol or inactivation were uneconomical; should not impair the technological properties of ethanol and adversely affect its further use. It is difficult to pick denaturation additive, which would fully meet all these requirements, but the creation of denaturing compositions should be possible to consider the given requirements.

As a general denaturing substance denaturation pyridine bases, kerosene, ketones oil, turpentine, waste production turpentine and thinner called solvent M – a mixture of ketones with some higher alcohols (methyl, methylpropilketon, propyl alcohol, isopropyl alcohol, etc.) are used.

Denatured alcohol is added in different colors that give it the desired color to distinguish it from drinking alcohol (eg, basic violet K according to National Standard 22698-77). Here are some recipes for general-purpose denatured alcohol:

1. 100 decaliters of anhydrous ammonia in denatured alcohol: kerosene – 0.5 dal, ketones oil or turpentine main straps – 0,5 dal, paint solution (0.4 g in 1 liter of 82% alcohol) – 0,1 dal. Instead of ketones can be taken 0.25 dal pyridine bases.
2. 100 decaliters of anhydrous ammonia in denatured alcohol: solvent M – 1.0 dal; paint – 0,1 dal.
3. 100 decaliters of anhydrous ammonia in denatured alcohol: solvent M – 0.25 dal, straps turpentine – 0.25 dal, paint solution – 0.1 dl.

Denatured alcohol of general denaturation must meet the following requirements:

- concentration of alcohol – 82% vol. of alcoholmeter glass for class 0.1 (admitted deviations from strength + 0.2%);
- have stable odor, which doesn't disappear when diluted with water to denatured alcohol strength of 40%;
- the color of denatured alcohol should be blue or blue with a purple tinge, depending on the color added denaturing substances;
- denatured alcohol reaction is neutral or slightly acid, denatured alcohol should not contain denaturing substances not permitted by the Ministry of Health;
- burning of denatured alcohol should be smooth, calm and without splashing the sample after burning denatured alcohol allowed for a small (a few drops) remaining colored water;
- allocation of soot, steam and suffocating gases during combustion of denatured alcohol are not allowed.

Characteristics of ethyl alcohol denatured by Technical terms 18.511-99 are shown in Table. 3.3.

There are some substances that cannot be used as denatured alcohol: substances that adversely affect the stability of fuel, engine and fuel system; hydrocarbons with a boiling point above 225°C; methanol; pyrrole, turpentine, ketones and resin.

Table 3.3

Characteristics of ethyl alcohol denatured by Technical terms 18.511-99

Number	Indicator	Unit	Characteristics and rate of norm				
1	Appearance		The transparent liquid without extraneous particles				
2	Color		Proper to used color				
3	Smell		Typical for ethanol, resistant. Should not disappear when diluted with water to the alcohol strength of 40-50%				
4	Volume fraction of ethyl alcohol, not less	%	95.0	91.0	95.0	98.0	98.0
5	Volume fraction of methanol, not more	%	6.05	0.20	2.50	0.03	0.1
6	Volume fraction of cyclohexane, not more	%	-	-	-	0.5	0.5

For technical purposes, ethanol is denatured with special substances that do not affect the process, which uses technical ethanol. The main denaturing agents in the EU and the CIS are petroleum ether, toluene, diethyl ether, crotonic aldehyde, propylene glycol, ethylene glycol and others. If the dye degrades the technological properties of alcohol and affects adversely on continued use of alcohol, it cannot be added in denatured alcohol. Denaturing substances added to the special denaturing technical alcohol is in an amount of 0.08 to 15%.

3.2. Feedstcok for Bioethanol Production

All sugar and starch plants or lignin cellulose biomass may be used as the feedstock for the production of bioethanol. In the world practice bioethanol market is based on the use of such energy crops as sugar cane, corn, wheat, rye, barley, sugar beet, sugar sorghum, Jerusalem artichoke, Manihot esculenta, yam, potatoes.

Growing and harvesting grain and row crops intended for processing into ethanol are not different from their production for food purposes. The level of demand is determined by the quality parameters of the specified crop and the economic indicators of production and sales.

The main requirements for raw materials are low cost, ease of processing, high yield of ethanol from 1 ton of raw material and from 1 ha, positive energy balance, low costs in transportation. The type and quantity of raw materials ac-cumulated in starch, sugar or glucose depends on the complexity of biocon-version and the amount of obtained bioethanol. The estimated bioethanol output data after feedstock fermentation is shown in Table. 3.4.

Table 3.4

The Estimated Output of Various Crops and Possible Output of Bioethanol from Biological Feedstock

Crops	Planned yield	Bioethanol output	
		from 1 ton of raw materials, l/t	per 1 ha, l/ha
Sugar beets	900	100	9000
Jerusalem artichoke	300	87	2610
Maize (corn)	70	416	2912
Wheat	50	395	1975
Barley	58	370	2150
Sugarcane	650	70	4550
Cassava (Manihot esculenta)	120	180	2160

The climate and type of soil types determine the amount of plants that can be grown in different geographical areas. Therefore, the choice of crop, which has the highest economic and environmental efficiency in growing and processing it into ethanol, is most dependent on the geographical location of the country, the availability of fertile soils, total precipitation and solar radiation.

In tropical countries (Brazil, Argentina, Thailand), the most common feed-stock for ethanol production is sugar cane, in the northern hemisphere (U.S., EU, Canada) – corn, grain, sugar beets.

In the world practice, bioethanol market is based on the use of sugar containing crops (sugar cane, sugar beet, sugar sorghum), starch containing (corn, wheat, triticale, barley, rye, potatoes, sweet potatoes, artichoke, cassava) and cellulose (miscanthus, svitchhras). In the biological feedstock structure of bioethanol production in Ukraine, the leading proportion belongs to grains, sugar beets and molasses, inconspicuous part belongs to potato, artichoke, chicory.

Cereals are starch raw materials, traditional for Ukraine, Europe and North America. Bioethanol can be obtained in the processing of any grain, including unsuitable for food or feed purposes. The content of starch in the dry grain (humidity 14%) of different crops are as follows (Table. 3.5).

Table 3.5

The Content of Starch in Various Starch crops

Crops	Starch content, %
Corn: starch toothed silica	 61-70 58-64 54-71
Wheat	48-57
Rye	46-53
Barley	43-55
Millet	42-60
Oats	34-40
Grain sorghum	58-66
Rice	65-73

The starch content depends on the type of crop and the soil and climatic conditions of its cultivation. The economic efficiency of the use of certain types of feedstock determines the cost of a ton of starch in it. In corn, except starch, there is much dextrin (up to 6%), which is also used for ethanol.

The free-flower pellicle grain contains from 1.5 to 2.5% of cellulose. The un-refined grains with floral pellicle may contain more – from 4.4% in a barley to 10% in oats. Using the technology of preparation of mash from corn cellulose, pulp is partially converted into fermentable sugar, and the output of bioethanol increases.

The technologically important indicator of grain feedstock is pentosan con-tent – a part of the hemicellulose. These substances highly increase the vis-cosity of the mash, so you need to use special enzymes to liquefy it. A large number of pentosans is in oats (13-15%), barley (9-13%), rye (10%), in wheat – less.

The nitrogenous substances of grains consist mainly of proteins (7.25%) and a small amount of free amino acids. Proteins play an important role in the tech-nology of preparation of mash and fermentation. On the one hand, they in- crease the viscosity of the intermediates and the process require the use of prote-olytic enzymes in the preparation of the mash, on the other, they're the supply source of nitrogen for yeast. The fat content of the grains is relatively small – from 1.5 to 5%; except for corn, which, depending on the grade, contain up to 7%.

Fats prevent foaming of the mash, which reduces or eliminates the need for defoamers. Besides starch, there are fermentable sugars in corn, mainly sucrose – 0.6 to 7%.

The Grain market is the most perfect and predictable in the world. This is deter-mined by several factors. Grain products are among the vital, the most popular and affordable food among the population. The Growing of grains due to natural climatic conditions may not be possible throughout the globe, but the grain is the perfect product for long-term storage and delivery by any transport. De-spite of having the apparent benefits by a group of countries in grain export or import, this market isn't completely monopolized. It can be attributed to more oligopolistic markets. The price conjuncture is quite predictable, because it is closely related to produce volumes, stocks and demand in the international grain market, as well sa the prices in the domestic markets of the exporting countries.

Many countries that are major importers or policies of which is related to the active export of grain, track trends in the world market and their own place on it. As for Ukraine, it was not a separate entity of the world market until obtain sovereignty, its potential is taken into account only in the USSR, and only in the last decade of the 20th century the first information about Ukraine appeared in the international grain market surveys. In our opinion, it is not making sufficient efforts to become an active trading partner, to find their niche in the global grain market, although it has the need and the potential for this. Even-tually, the country should decide on a place in the world grain production, possibilities of its exports, imports feasibility of certain species of domestic grain production competitiveness on the world market in order to develop export-import policy in respect of this strategic product for the country in the future.

The potential grain production in Ukraine in 80's years of the 20th century was caused not only by favorable climatic conditions, but rather high level of intensification of grain production, compared with the previous and following years. In 1990, 132 kg of mineral and 6.5 tons of organic fertilizers were contributed per 1 ha of grain in Ukraine (in developed countries at that time – 300 kg of active ingredient of mineral and 12-15 t of organic fertilizers)

The nineties were not the prosperous period for any agricultural sector of Ukraine, including grain production. Although production figures were slight-ly better than in unprofitable livestock, a sharp decline in productivity, dete-riorating the quality of food grains were realities that are compounded over the years. This situation was not only a cyclical crisis that followed the years of 1989-1990, the most favorable period for the grain industry. The Grain farming exposed to the general economic crisis, transition and structural crisis which broke proportion of value as between sectors of agriculture, and between agriculture and other sectors of the national economy. The crisis was deep and protracted.

Because of a striking disparity in the prices of inputs for agricultural and grain products, consumption of fertilizers in agriculture decreased by 3.2, cor-relation between nitrogen, phosphorus and potassium have been deteriorated, the use of herbicides, insecticides and retardants reduced greatly the yield ofgrain per area unit have been and caused the significant quantitative and qualitative yield losses. The high cost of water and energy significantly limited the irrigation zone of risky agriculture and caused a decrease in gross output. Because of the high physical deterioration of means for harvesting grain, annually com-pounded during the first half of the 90s, the lack of an appropriate framework for storing grain at farms after the reduction of the state order and denial of service grain companies, the total grain losses at all stages of the reproductive process achieved nearly a third of biological crop in some years.

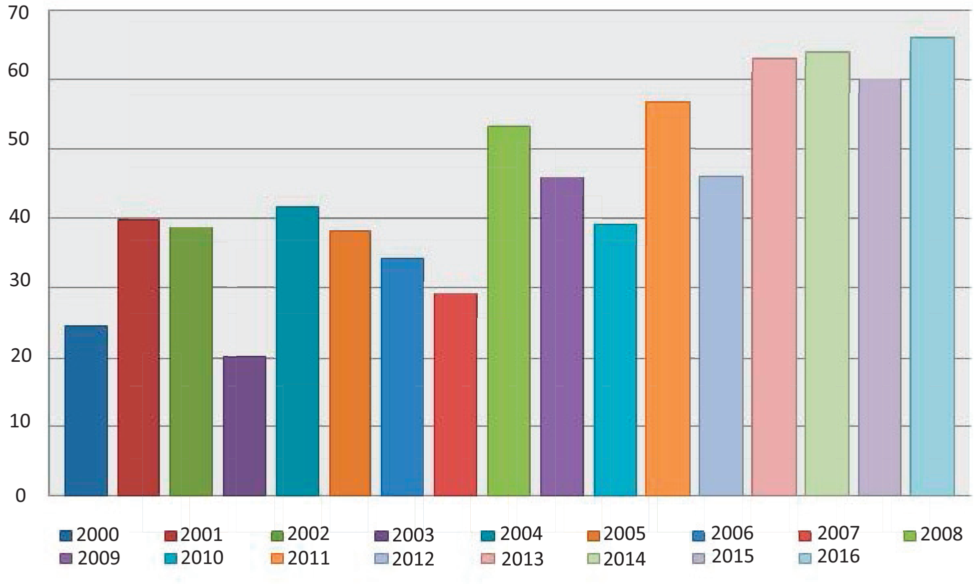


Figure 3.4. Dynamics of Grain Production in Ukraine, mln t

Today, among all the crops that are growing in Ukraine, the leading share be-longs to grain (wheat, rye, barley, corn, oats, millet, sorghum). In Ukraine the out-put of grain depends on the weather to some extent. That's why the volume of production is not easily predictable and it varies from year to year. However, the av-erage yield of grain is stable and reaches over 50 million tons in recent years (Fig. 3.4).

The analysis of global market shows that Ukraine is a leader in the produc-tion of grain along with such large countries as the US, China, India, Russia (Fig. 3.5). However, while the US export is 18.5%, China – 0.3%, the EU – 9.3%, India – 4.3% of their gross production of grain to the world market, Ukraine exports 41% of grain. However, considering the dependence on en-ergy imports, unstable agriculture and high unemployment, especially in ru-ral areas, it is not appropriate to export almost half of corn, grown on Ukrai-nian black soil, as a raw material.

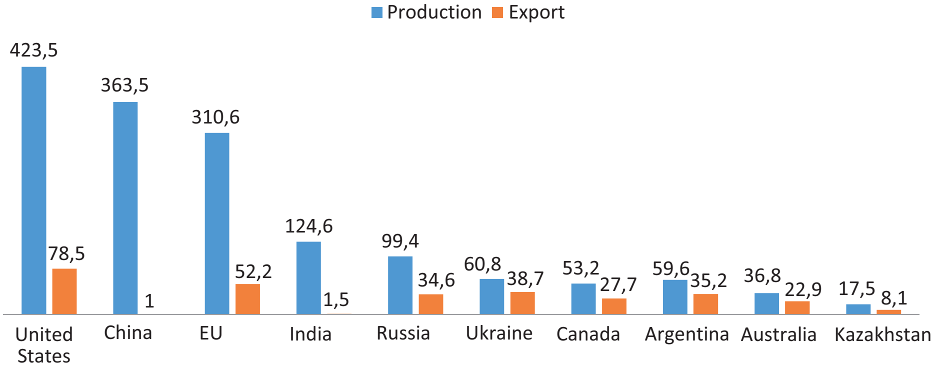


Figure 3.5. World Total Grains Production and Export, 2015/16 MY

During the processing of grain into alcohol, dried distillers' grains with solubles (DDGS) are being formed. It should be used for feeding cattle, pigs, poultry, small livestock and fish. In addition, because of rising fuel prices, liq-uid DGS (with solids content of 5.5-7.0%) transportation over long distances is unprofitable. It is better to use dry DGS.

DDGS is a secondary liquid product of grain stillage processing, a valuable protein and vitamin-containing feed for livestock and poultry. There are valuable ingredients in DDGS: protein – up to 28%, which is equivalent for the effective use of sunflower meal protein, carbohydrates – 16.5%, fat – 6.0%, minerals – 2.4%. The valuable characteristic of DDGS is that it contains vitamins, tocopherols, ergosterol, which serve as regulators of metabolism in animals and about 17 amino acids (lysine, glutamic acid, glycine, valine, leucine, isoleucine, proline, and others). DDGS has all the nutrients contained in raw materials, but their quantitative correlation is slightly different. In DDGS, for example, there are more proteins than in the original raw material, and much less carbohydrates, because they are the most used in the form of starch and sugar in the alcohol processing. High energy value and protein content makes them useful for feeding cattle for meat. Dry food insertion into the diet can significantly reduce the consumption of forage.

In addition, DDGS can be administered to high-yielding cows rations, due to lower solubility of the protein in this product than forage. The amount of DDGS depends on the cow productivity, crude protein content in the diet and in avarage equals to 300-350 g per 1 liter of milk.

In economic terms, the use of dry products has high profitability, since DDGS issignificantly cheaper than feed grain, and it generally reduces the cost of food and, therefore, reduces the cost of production.

Thus, complex processing of plant materials has particular importance in the terms of market economy. Development and implementation of flexible technological scheme of obtaining several products enables not only more widely to process raw materials but produce competitive products according to market demand. Use of DDGS for fodder purposes is the solution of a number of economic and environmental problems.

An important cereal crop for ethanol production in Ukraine is corn, which holds a special place in the domestic and world grain production. For yield potential, diversity of use is the most distinguished among other cultures. Maize, as one of the few crops, has found the widespread use in food, starch and molasses, biofuel, microbiological, medical and other industries, has considerable fodder properties. Corn consumption in rations in Ukraine is minimal and most of grown products currently are being exported (Fig. 3.6).

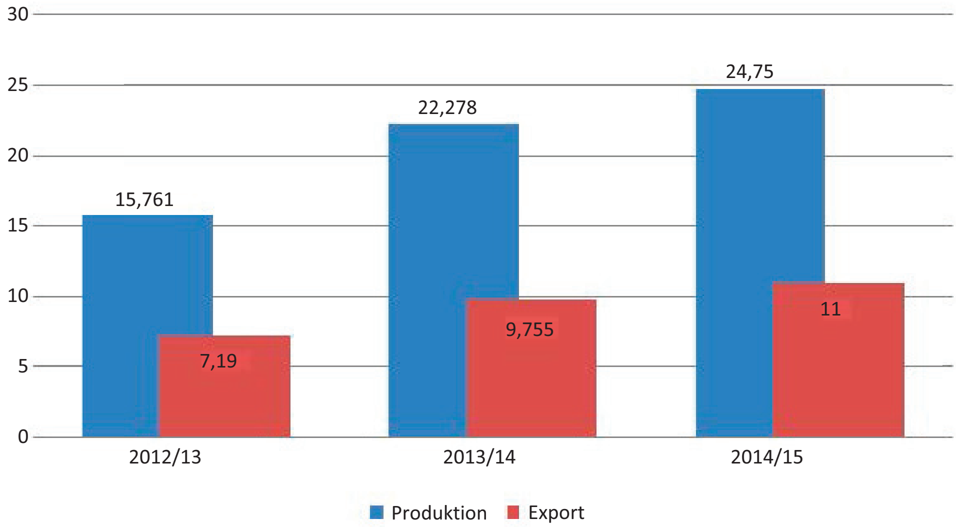


Figure 3.6. Production and Export of Corn in Ukraine, mln t

The data in Fig. 3.6 shows that the production of corn is gradually increasing in Ukraine. In particular, in 2013, there was a record for the last decade in this positive trend. So, the acreage (more than 4.795 million hectares) and yield (54.2 centners/ha) helped to create the largest total yield volume – 26 million tons of corn. Corn exports was 16 729 thousand tons in 2013 Therefore, considering the bioethanol output of 40 liters from 1 kg of grain (including that at 20°C ethanol density is 0.79 g/cm 3, with 1 ton of corn can provide 0.316 tons of bioethanol), processing the exported volume, we could get 5.286 million tonnes of bioethanol.

Depending on morphological features of plants, chemical composition and process parameters, corn is divided into botanical subspecies: dent corn, flint corn, pod corn, popcorn, flour corn, and sweet corn. For the bioethanol production, the most suitable types of corn in terms of agriculture Ukraine are flint and dent corn.

Corn grains differ significantly from other grain cereals by size. The weight of 1000 grains most varieties and hybrids of maize is 170-800 g, which is significantly higher than the same weight of wheat – 30-40 g. Unlike grains of other cereals, corn embryo is very large, the mass of which is 7,6-15,4 % of the grain weight, and wheat germ weight is only 2,5-4,2%.

The peculiarity of the maize grain structure is that the endosperm has a horn-view, which is located on the periphery of the grains and starch grains never completely fill the cavity cells. The spaces between cells are filled with granular protein deposits. The powdery part of the endosperm, located inside the grain, starch grains are round, larger, they completely fill the cavity cells and are almost unrelated.

The proportion of morphological parts of the grain is different for certain varieties of corn, depending on soil and climatic conditions for cultivation. In dry matter, the proportions of grain morphological parts are the following: shell – 5-6%, germ – 8-14%, endosperm – 79-85%.

The main substances that determine the nutritional and economic value of grain corn are proteins, starch, sugar and fats. Their content varies widely and depends on the origin and grain growth conditions.

Chemicals in the grain are unevenly distributed in its various morphological parts: the shell, germ and endosperm. Cellulose (18.72%) and pentosan (20.33%) are concentrated in the shell; the bulk of starch, cellulose and pentosan in a small number are concentrated in the endosperm (0.5 and 1.3% respectively). In germ, there are fat (35%), cellulose (5.9%) and pentosan (4.3%). Compared to other grains, corn contains the maximum amount of carbohydrates in grain (75-85%), which are starch, sugar and fiber.

The starch and sugars are the most frequently used substances in order to produce the bioethanol.

Starch. Starch grains are formed from two fractions: amylose and amylopectin. Depending on the variety of maize, starches contain 30-25% of amylose and 70-75% of amylopectin. Both of these polysaccharides are built from the remnants of D-glucose. Amylose molecule is a linear chain with α-1,4 links between the glucose residues, and amylopectin glucose residues form a branched form links with α-1.6 in the points of branching. Each fraction has specific properties and is being hydrolyzed by different enzymes.

The content of amylose in some industrial corn varieties can reach up to 70%. Except the starch, in corn there is a significant number of monosaccharides in corn.

Corn grains contain the protein (10-14% on dry matter). More than 40% of proteins include prolamin (zein), which is characterized as biologically inferior, because it hardly contains essential amino acids such as lysine and tryptophan. Except zein, there are such proteins as albumin, globulin and glutelin. These proteins belong to the group of biologically valuable and contain essen-tial amino acids.

Proteins in the corn grain are distributed unevenly among its parts. Embryos holds about 70% globulin of whole grains. Zein and glutelin prevail in other parts.

The fat content in corn is quite high (3.5-7.0%) and low in the endosperm and shell (0.64-1.06%). Over a third of fat is concentrated in the herm. The dent and flint corn have more fat than other types. Corn oil is composed primarily of a mixture of triglycerides and contains many fatty acids, including 56.2% of linoleic, oleic (30%), about 10% of palmitic and stearic (3%).

The average chemical composition of different corn subspecies shows that it is very promising crop for biofuels. By corn processing on an integrated circuit in the plants, we can receive feed product, bioethanol, biodiesel and biogas.

At the same time, corn is an intense crop, the cultivation of which requires large amounts of water, fertilizers and pesticides. Because of the failure of crop rotation, low efficiency of irrigation, inadequate provision of agricultural machinery and small quantity of fertilizers, Ukraine now can not provide high yields of corn, that is why the output of bioethanol from 1 ha of this crop is much lower than in leading ethanol producing countries. The corn yield equals to 62.2 c/ha in Ukraine in 2013 (in 2012 – 46.3 c/ha), and 90-100 kg/ha in the U.S. The use of genetically modified varieties plays a significant role in ensuring high yields of corn.

One of the reasons that hinders the increase of grain corn is reducing performance of material and technical equipment. We know that corn, with extended growing season, demands in terms of care. To generate 50 kg of grain, depending on the biotype of hybrids and other conditions, the corn is extracting 130-150 kg/ha of nitrogen, 40-50 kg/ha of phosphorus and 130 kg/ha of potassium from the soil. But due to the high cost of fertilizers, maize fertilization was extremely limited in recent years.

Large grain losses are caused by the high degree of crops contamination. According to the Institute of Sugar Beets, during the growing period, 1887 weeds may germinate on 1 m2 of arable land (5 cm depth) under the optimal conditions in the zone of sufficient moisture – 1121, in insufficient. According to the observations and accounting of Institute of Grain Farming NAAS, corn crop losses at the average weed-infested reach 25-30%, at strong weed-infested – up to 40% or more.

By reducing the overall crop and high potential pollution, the studies show that combination of farming and chemical measures to combat them is the most effecient method of weed control.

The transition of many farms to superficial tillage system without the use of herbicides contributed to a dramatic increase of contamination of maize crops. Considering that the area of maize crops should be treated with herbicides, due to the lack of financial resources of enterprises, which are very limited and account for only 25-30%, this creates considerable difficulties in carrying out the care of culture, significantly reduces the moisture content of the soil and negatively affect its fertility.

Describing the reasons that hinder the increase in production of corn, we can not ignore the problem of technical equipment of the industry. It is known that intensive and mechanized technology are based on a set of machines and tools, to ensure compliance with all recommended technology elements. The introduction of new technologies of corn depends largely on the technical feasibility of farms.

However, with the increasing of production of ethanol fuel, the demand for feed grain for its production is also increasing, seeding area under food grain are reducing, creating a deficit and generally increasing the cost of grain. Therefore, the most promising feedstock for bioethanol production and common crop in our country is sugar beet and sugar production intermediates. Sugar beets have traditionally been a priority crop in Ukraine. Soil and climate zone of Ukraine meet needed biological features for growing sugar beets. Ukraine created the separate productive forms of sugar beets cultivation that radically changed the technology culture. On beet fields, even before the World War II the movement for the obtaining 5 tons yields has been emerged and subsequently acquired mass distribution. However, by losing of export opportunities in the early 1990's, the production of sugar beet in Ukraine has been decreased significantly and now the level of its production equals to internal needs in sugar (Fig. 3.7).

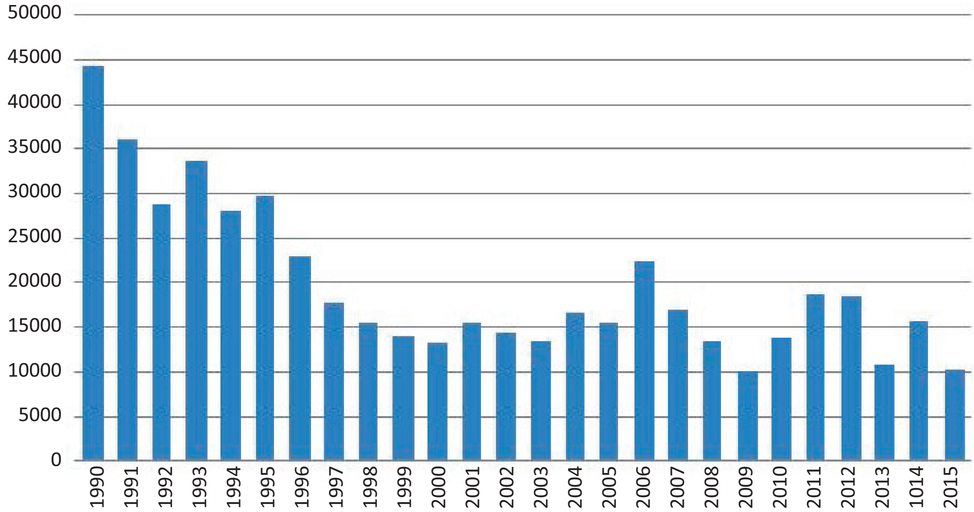


Figure 3.7. Dynamics of Gross Sugar Beet Harvest in Ukraine, thousand tons

The number of sugar factories has decreased in recent years. The plants have been dismantled and can not be restored. Material and technical bases of existing plants are physically and mentally used. The main reasons of negative developments in the field are the following: the loss of foreign markets of sugar; insufficient recovery work and competitiveness ensuring of domestic sugar; imperfect management systems; failures in privatization; artificial bringing entrprises to bankruptcy; non-equivalence for industry products and the inputs that led to deindustrialization of beet-sugar production; reducing gross yield of sugar beet through weediness of fields, infestation of crops by pests and diseases, reducing the number of chemical and organic fertilizers in 3-4 times, reducing acreage, lack of implementation of new technologies, the lack of highly qualified experts with knowledge of the foundations of a market economy, including management and marketing; excessive import of raw cane sugar; application of tolling schemes of sugar beet processing, barter and illegal import to Ukraine of sugar and sugar-containing products.

In case of rejection of radical measures on stabilization of beet-sugar industry, overcoming negative processes and phenomena that have accumulated in recent years in this area, we may see a drop in acreage under sugar beet and its yield and, as a result, reduction of incoming feedstock to sugar factories and declining of sugar production volumes; reduction in yield of crops in grain-beet crop rotation due to violation of scientifically grounded crop rotation plants; increase of sugar imports for the population within the limits of physiological and consumption of industrial enterprises using sugar as raw materials and imports of molasses for the production of alcohol, yeast, food acids and other products; the substantial loss of fodder balance posed pulp and tops as by-products of beet-sugar production; the subsequent closure of sugar mills and the consequent loss of jobs and increased social tension in society; significant outflow of foreign exchange funds of the national economy due to imports; weakening of economic security.

Now there is extremely difficult situation in Ukrainian sugar beet industry. The cost of sugar beet and sugar are growing rapidly, and the payback is decreasing. Instability of purchase prices for sugar beets, their artificial overstatement or understatement of income cause the constant changes, low profitability and even losses. In addition, this instability creates increasing of riskiness of sugar beet and thus lost of interest of farmers to the industry.

Setting up the production and consumption of biofuels from sugar beets can be used as stabilizing factor for the sustainable development of domestic sugar beet production. The experience of leading countries shows that clear, understandable and flexible legislative levers of state regulation of economic relations in the sugar industry as well as production and use of bioethanol from sugar beet and sugar beets production waste play an important role in these countries.

Despite the fact that the largest producers of ethanol in the world use corn and sugar cane as a feedstock, the highest output of bioethanol from 1 hectare can be provided by sugar beets. As a comparison, the yield of ethanol from one hectare of sugar cane in Brazil is 4700 liters, from 1 hectare of corn in the US – 3000 liters. At the same time, 1 ha of sugar beet can produce 9,000 liters of bioethanol (by providing the yield of 900 kg/ha).

Bioethanol can be produced directly from sugar beets as well as from sugar production waste (molasses), to obtain alcohol from intermediates of processing roots – from beet juice or sugar syrup.

Molasses is a thick liquid that has a high viscosity and dark brown color, sometimes with a greenish tinge and specific smell caused by the products of caramelization of sucrose and melanoidins and a small amount of trimethylamine and other products of betaine decomposition.

The chemical composition of molasses is very complex and depends on such factors as the soil and climatic conditions of beet cultivation, methods of data collection, technological modes of processing in sugar factories, as well as the storage conditions of molasses. The main components of beet molasses are shown in Table 3.6. The density molasses is 1.3985 t/m^3 with the solids content of 78%. The main component of molasses is sugar that is presented by sucrose (45-50%). In terms of fermentation and receiving alcohol, the valuable component is invert sugar – a mixture of equal molar amounts of glucose and fructose. Invert sugar content in molasses is 0.5-1.5%. Rraffinose content can reach from 0.5 to 2.0%. Invert sugar and raffinose are transferred to sucrose and form the fermented sugars.

Table 3.6

The Contents of the Main Components in Beet Molasses, %

Dry matter	76-84
Sucrose	46-51
Total nitrogen	1.5-1.8
Reducing substances	1.0-2.5
Betaine	4.0-7.0
Raffinose	0.8-1.2
Lactic acid	4-6
Acetic acid	0.2-0.5
Formic acid	0.2-0.5
Coloring agents (melanoidins, caramel)	4-8
Ash, including the mass of ash	6-10
K2O	68
Na2O	12
CaO	6
SO3	0.5
P2O5	0.5

All other substances are combined as non sugars, the composition of which determines the technological properties of molasses as a feedstock for alcohol production.

The non sugars of molasses are divided into two groups: organic and mineral non sugar. Organic part of non sugars has no nitrogen and nitrogen-containing compounds.

Nitrogen-free organic substances. They are represented by alkaline degradation products of sugars, organic acids and melanoidins.

Alkaline decomposition products of sugars. Invert sugars, especially fructose, under alkaline conditions of producing are rapidly decomposing by heating. First of all, as a result of mutual keto-enol tautomerism, the conversion of glucose and fructose occurs, and new monosaccharides such as mannose and psicose are forming. With the expansion of monosaccharides, the non-volatile form painted acid and higher humic acid are forming, a small amount of lactic and volatile acids – acetic and formic.

Caramel is the name of a complex mixture of products formed in the thermal decomposition of sucrose and monosaccharides. The composition of caramels includes anhydrides sugars, dark-colored and other compound.

Melanoidins are also a complex mixture of products of the chemical interac-tion of reducing sugars with amino acids. Except the nonvolatile colored compounds with a small amount of nitrogen, they also contain aliphatic aldehydes, methylglyoxal, diatsegil, acetoin and others.

The color of molasses is caused by coloring substances, which are formed by alkaline scenario of monosaccharides and melanoidin reaction. Most of these dyes form the aqueous solutions.

4-6% of molasses substances are in colloidal condition. Colloids are a group of colored products of alkaline degradation of sugars that have a negative electrokinetic potential and colloids with a colored product of melanoidin reaction have positive electrokinetic potential. Yeast cells are negatively charged, so the yeast is indifferent to the products of alkaline degradation of sugars, but oppositely charged yeast cells adsorb melanoidins on the surface. The melanoidins impede the exchange between cells and nutrient medium, and the yeast become dark-colored.

Colloids of molasses in large numbers is a cause of foaming during fermentation of molasses wort.

Organic acids which are formed of calcium hydroxide insoluble salt (oxalic, citric and wine) are mostly removed from juice during defecation, other acids (glu-taric, malonic, adipic, succinic, lactic, malic etc) proceed into molasses. There is some formic acid like volatile (0.1-0.4%), acetic acid (0.6-1.3%), propionic (up 0.4%). Most of the volatile acids are formed by microorganisms. In molasses almost all volatile and non-volatile acids are presented as salts of potassium and calcium.

Upon the acidification of molasses by mineral acids, salts form the volatile free acid. Free acids are more toxic to yeast than their salts. The inhibitory effect on yeast cells increases with increasing of the number of carbon atoms in the acid molecule, i.e. its molecular weight. Alcohol yield reduction occurs in such concentrations of volatile acids in the molasses: formic – 0.3; acetate – 1.5; propionic – 0.4; oil – 0.15 and caproic – 0.19. Such concentrations can contain all the volatile acid, except the caproic.

Nitrogenous substances. The content of these substances in molasses depends on the amount of nitrogen fertilizer, sediment that fell, the temperature during the growing season, and the longevity of roots: it increases with increasing doses of fertilizers and decreases with increasing amounts of precipitation, lower temperatures and increased longevity beets.

Molasses contains from 1.2 to 2.3% of total nitrogen, which consists mainly of amine (42%) and betaine nitrogen (50%). There is amide (3%), ammonia and nitrate (3%), protein nitrogen (2%) in a small number .

The content of nitrogen absorbed by the yeast in molasses is from 12 to 20% of total nitrogen. 0.25% of digestible nitrogen are enough for normal yeast life.

The amount of amino acids transfered into the molasses from beet is only 50-60%, the aminobutyric acid is formed during the beet processing with glutamic acid by decarboxylation. Glutamic acid easily cleaves the water turning it into the cyclic pyrrolidone-5-carboxylic acid, and 75% of it is contained in molasses.

The highest number of amino acids in molasses belongs to glutamic acid (1.6-5% of nitrogen). It also contains leucine and isoleucine – 0.7-1.5, valine and methionine – 0.3-0.6, aspartic acid – 0.3-0.5, tyrosine – 0.02-0.40, alanine – 0.6-1.2, serine – 0.6-2.0% of the total amount of nitrogen, and other amino acids.

By the fermentation in a nutrient medium, the amino acids form the alcoholic fermentation byproducts – higher alcohols with leucine – isoamyl, valine – isobutyl, aminobutyric acid – N-propyl alcohol, a part of the by-product alcohol distillation – fusel oil.

Betaine $(CH_3)_3N – CH_2)$ is the organic base contained in the beets and almost completely converted into molasses. The molasses contains the amines – betaine thermal decomposition products – trimethylamine, dimethylamine, ethylamine and methylamine. They give a bad taste of molasses alcohol, impair its organoleptic properties, but do not affect on the quality of bioethanol.

Betaine is practically not absorbed by alcohol yeast races and almost all remain in the vinasse after distillation mash. However, betaine is an extremely important matter for the poultry industry, so its selection and obtaining as a commercial product greatly affect the cost of bioethanol production and enhance its competitiveness.

Thus, in technological view, the molasses is the best feedstock for bioethanol production. Except the high content of fermented sugars, there are substances that are necessary for normal yeast life. In addition, there is no need for suc technological operations as disintegration, boiling, liquefaction and saccharification that are necessary in the processing of starch-containg products.

Getting sugar from sugar beets by extraction, as they do at sugar factories, we can receive the diffusion juice – water extract of sugars and non-sugars contained in the fabric root. Exemplary juice composition is shown in Table. 3.7

Table 3.7

Exemplary Juice Composition of the Raw Juice,%

Dry matter	13-15
Sucrose	11-13
Pupl (mash)	2-3
pH	5.5-6.5
Goodness (purity)	82-89

The diffusion juice can be used for processing into ethanol or mixed with molasses. During the juice processing at sugar factories we can get high concen-tration (65% of solids) sugar solutions. These syrups have the different degrees of purity (goodness) and can be used to produce bioethanol. Sugar producers often remove some intermediates with lower purity from production process. It is more profitable than their costly cleaning for getting the crystalline sugar.

The production of bioethanol from sugar beet will not only contribute to the formation of our country's energy security, but also help to stabilize the sugar beet industry. Getting the harvest of sugar beets at the level of 800-1000 c/ha is possible in Ukraine. Now with minimum technological support, the domestic sugar beet varieties, bred by scientists of the Institute of bioenergy crops and sugar beet NAAS, let us get such a high yield. Thus, we can avoid the cost of purchasing imported seeds and using foreign production technologies.

In addition, the production of bioethanol from sugar beets requires 20-30% less energy than a grain material. This is due to the fact that the production of ethanol from starch crops (corn, wheat, sorghum) must first carry out hydrolysis of materials using enzymes to break down starch and receiving glucose.

DDGS is an extremely important by-product of the processing of sugar beets. It is a residue after stripping alcohol from the mash. It looks like light brown liquid. Content of solids is 3-8%. Previously, the molasses DDGS was considered as waste and dumped on fields of filtration and causing the environmental pollution. However, more effective way to use molasses DDGS is its dehydration and anaerobic fermentation to obtain biogas. The part of the natural gas used by sugar plant, can be replaced by environmentally friendly biogas derived from anaerobic fermentation of DDGS.

Sugar beet is a necessary crop for rotation. A lot of organic fertilizing are being made during sugar beet growing. The growing of sugar beets generally improves the soil fertility and provide the yield increasing of other crops, especially cereals. In addition, sugar beet turnip can be plowed that can give more than 10 tons of organic fertilizer per 1 hectare.

As for the index of energy balance (the ratio of the received energy to spent), according to the Ministry of Trade, Economy and Industry of Japan, currently the highest rate of energy balance provides ethanol from sugar cane (Fig. 3.8).

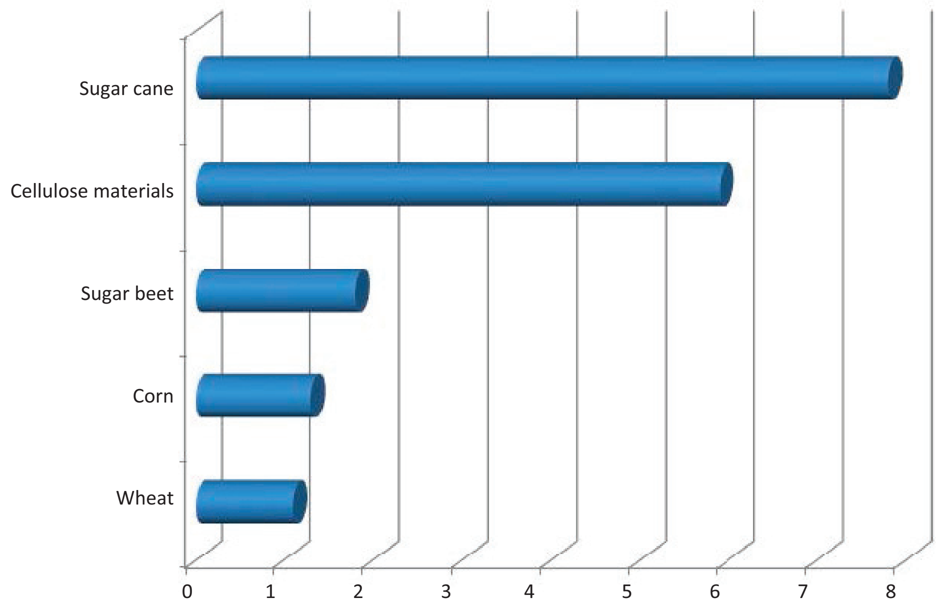


Figure 3.8 The Balance of Energy in the Production of Ethanol from Various Kinds of Feedstock

Biofuels produced from cellulosic feedstock take the second place on the effectiveness of the energy balance. In order to reduce the volume of food agricultural crops used for biofuels production, the U.S. are implementing second-generation biofuels, which is made from non-food cellulose materials (miscanthus, svitchhras, perennial grasses, corn stalks, crops residues). However, despite the significant funding, laboratory research and technology improving, second-generation biofuels are not yet competitive compared with conventional fuels or first generation biofuels.

According to the data of Ukrainian research institute of alcohol and biotechnology of foods (URIABF), 80-100 liters of bioethanol can be produced from 1 t sugar beet. To produce 1 ton of bioethanol 12,6-15,7 tons of sugar beet should be processed considering that ethanol density is 0.79 g/cm^3 at the temperarure of 20°C; 0.079 tonnes of bioethanol can be produced from 1 t of sugar beets. Thus, in the case of sugar beet cultivation in Ukraine at the level of 1990 and the processing of the harvest that is not involved in the production of sugar (about 25 million tons) to bioethanol, Ukraine will produce an average of 1.975 million tons of bioethanol.

In 1970, Brazil was the first country among the current major producers of bioethanol, which introduced its industrial production in factories that previously processed sugar cane only for sugar. Since the early 2000s, France, Germany, Czech Republic, Great Britain and Poland also introduced the production of sugar and ethanol within single plants. These countries, unlike Brazil, have begun to use sugar beets as feedstock instead of sugar cane. Volumes of production of sugar and ethanol are adjusted depending on market demand. Thanks to this construction, sugar beets producers has no problems with the sale of their crop in the years when the sugar demand falls in the domestic market, and access to foreign markets is limited. The simultaneous production of ethanol and sugar in one production area stabilize activity both of the sugar industry and the entire agricultural sector.

The planned withdrawal of sugar-beet industry from crisis, transforming it from extensive to intensive development, gradually increase production of its own sugar beet and sugar to provide the country demand with sugar, and gradual recovery of the export potential of the industry will reduce the production costs and increase profitability in the sugar industry, stabilization of prices for sugar beet and sugar to achieve full independence from imports of sugar and sugar products, access to the world sugar market. Implementation of these measures will make it possible to get every year a significant amount of molasses as biological raw material for bioethanol production.

For most CIS countries the sugar sorghum is very promising feedstock for bioethanol production. Sugar Sorghum – Sorghum sac- charatum Poiry – is an annual herb of the family of grasses that is cultivated in Asia, North and South America and Europe. Sorghum's stem is direct and reaches a considerable height (up to 3 m).

Sugar sorghum has many varieties which are characterized by the fact that their stem juice contains from 10 to 20% (sometimes more) of sugars. There is no other plant that could so quickly synthesize sugar in nature.

It can be harvested 90-100 t of sugar-containing biomass from one hectare. By the end of the growing season, the juice of the stems accumulates to 16-22% of sugar. Sugar sorghum can arrange to 40-50 t/ha of juice and 25-30 t/ha of dry mass that is used to produce bioethanol and biogas. Squeezed green mass is used for briquettes and pellets. Hectare of sugar sorghum crops can absorb 55 tons of carbon dioxide and emits about 40 tons of oxygen into the atmo-sphere during the growing season (125-135 days).

Sugar sorghum varieties with high sugar content in the juice were created in the US in the early 1940s due to the fact that during World War II there was the reducing of sugar production from sugar cane and sugar beets.

Sugar sorghum can be considered as a raw material, the transition from first generation to second. Companies that procese the sugar sorghum juice to bio-fuel could easily switch to pulp stems using, which is already partially prepared during extraction to hydrolysis by cellulase preparations.

The Institute of Food Biotechnology and Genomics National Academy of Sciences of Ukraine developed effective energy and resource saving solutions that enable to prepare the sorghum bagasse to saccharification with cellulose and receive solutions of simple sugars for subsequent fermentation to ethanol and butanol. For recent years, many agricultural farms in Ukraine are testing some varieties and hybrids of sugar sorghum created by members of NAS of Ukraine and received from abroad. There is a reasonable prospect to start sugar sorghum syrup processing not only in technical (as a substitute of molasses for the production of biofuels), as well as for food needs in one of the sugar factories of Ukraine. The parts of sugar sorghum total biomass are divided as follows (Table. 3.8):

Table 3.8

The Division of Plant Parts in Its Total Biomass, %

Stem	78-80
Waste (leaves)	19-22
Grain panicle	1-2

The results of investigation showed that the ethanol yield can range from 600 to 800 dal/ha and depend on the conditions of vegetation and plant technology of material processing. The sugar potential of sorghum as a raw material of first generation is higher in 1,5-2,5 times compared to corn and sugar beet.

Namely, the area of farmland for production of bioethanol (or butanol fuel) is in 1,5-2,5 times smaller than the area for traditional crops. It is much more profitable not only because of lower costs for land cultivation, but also due to cheaper raw material delivery to the factory (compared to sugar beets). Some biomass plants, including the one that contains the seeds, can be collected separately and used as fodder, partly offsetting the costs. This experience has been gained in the research of growing and processing the sugar sorghum.

The approximate chemical composition of stems, used for juice, is shown in the table. 3.9.

Table 3.9

Approximate Chemical Composition of Stems Used for Obtaining Juice, %

Dry matter	25-28
Water	72-75
Sucrose	6-8
Glucose	2-4
Fructose	2-4
Fermented sugars	15-18

The raw material for bioethanol production is sugar sorghum stalk juice; sorghum honey is a syrup obtained by concentration (evaporation) of sugar sorghum stalk juice; and cellulose stems of sugar sorghum – in the future.

We can get juice by mechanical grinding and extrusion of sugar sorghum stalks. The juice is a green and gray liquid, which defende the fragile sediment that consists mainly of proteins, chlorophyll and pulp. It is treated with lime milk, sludge and is used for cooking the wort. The syrup can be obtained by juice concentrating with evaporation. The syrup, so-called vari-etal honey, has dry matter content of about 65%. This syrup has a density of 1,33-1,35 t/m^3, and is stored for set time and used for bioethanol production like beet molasses.

Jerusalem artichoke (artichoke) – *Helianthus tuberosus L.* is a perennial herb with up to 4 meters (typically 1.5-3 m) height, forms tubers with a small potato size. Yield of green mass – 50-70 t/ha, of tubers – 35-60 t/ha. The tubers contain inulin soluble polysaccharide (14-18% or more), a small amount of free fructose and glucose.

Jerusalem artichoke tubers are stored poorly after digging (removal of land), so often this green mass is harvested in autumn and tuber – in spring. The composition of Jerusalem artichoke tubers varies with the wintering in the ground (tabl. 3.10).

Table 3.10

Composition of Green Mass and Artichoke Tubers

Name of component	Composition		
	Green mass	Tubers in autumn	Tubers in spring
Dry matter (DM)	17-19	18.2-20.2	18.8-21.0%
Total nitrogen, % of DM	1.4-1.6	1.8-1.9	1.5-1.6
Inulin, % of DM	7.5-7.9	78.0-80.0	14.5-16.5
Reducing substances, % to DM	12.0-13.6	4.0-5.2	71.0-73.0
Crude protein, % of DM	8.7-10.0	11.2-11.9	9.3-10.0
Phosphorus, % of DM	0.6-0.7	1.1-1.3	1.1-1.2
Ash, % of DM	14.0-15.0	6.2-6.4	6.6-6.8
Fat, % of DM	1.7-1.9	1.0-1.2	1.1-1.3

The main component of artichoke is inulin – a polysaccharide that is a polymer of D-fructose ($C_6H_{10}O_5$). The molecular weight is 5-6 thousand of units. While the hydrolysis in the acidic medium or under the influence of inulinase enzyme, D-fructose and a small amount of glucose are being formed. The increase of reducing substances in the tubers when they are wintering in the soil can be explained by hydrolysis of inulin under the influence of artichoke endogenous inulinase. We can observe the same intensive process in the wort preparation from shredded tubers. Formed fructose is fermented by yeast into ethanol as well as glucose.

The preparation of artichoke mash does not require any inulinase agents. Jeru-salem artichoke is being washed, crushed, and after it is mixed with water, adding nutrient salts if necessary. The crushed mass is hydrolysed under the influence of inulinase of artichoke at natural pH environment at a temperature of 50-55°C for 2-3 hours.

To prevent the development of extraneous microflora during the fermentation the chemical antiseptics or antibiotics can be added. There are known methods of inulin hydrolysis with mineral acids at a temperature of about 100°C, however, this process leads to the formation of furfural and hydroxymethylfurfural which inhibit the alcohol fermentation.

In general, the production of bioethanol in Ukraine is possible both in the sugar and alcohol plants. Concept of bioethanol production in Ukraine covers several areas:

1. Bioethanol production at existing sugar factories after equipping with respective production lines.

2. Reconstruction of existing distilleries and refitting them for the production of bioethanol.

3. The construction of new plants for the production of biofuels based on raw material cultivation areas.

The annual total capacity of distilleries is about 700 million liters of alcohol. According to estimates, the reconstruction of existing distilleries will bring the production of ethanol fuel in Ukraine up to 0.3 mln tons per year. Refinement of sugar plants with relevant production lines will make it possible to produce 1.65 mln tonnes of ethanol per year. Thus, even without the construction of new plants, taking into account all areas of development of biofuel market, we could receive 2 million tons of bioethanol per year in Ukraine.

Not all countries have a strong agriculture, so Ukraine should use its competitive advantages in the production of alternative energy – fertile soils, favorable agricultural infrastructure, a skilled workforce. In our country, considering the favorable soil and climatic conditions, there has been formed a strong raw material base, which includes basic starch, cellulose and sugar containing crops that give high biofuel output from unit of products.

3.3. World Experience in The Production and Use of Bioethanol

USA

Getting rid of oil dependence will remain one of the imperatives of the energy policy of the US government, the implementation of which will require technological breakthroughs. The reorientation of the US economiy on alternative fuel would be worth around 90 billion dollars per year, and today the country is spending more than 140 billion dollars for the purchase of oil.

Now, the extensive US energy policy that is based on the principles of diversification of oil and gas sources, as well as investment in new mines, the provision of sufficient energy at an affordable price is recognized as erroneous. Now, the declared priority of the US energy policy is a qualitative change in the structure of energy consumption and energy balance, which implies:

– a significant reduction in the consumption of hydrocarbons (10 million barrels per day) to 2031;

– large-scale production of alternative fuel, including ethanol and technological re-equipment of production and national vehicles fleet in order to use them;

– the introduction of energy efficient technologies and renewable energy sources at the national level;

– recovery off the coal industry development programs;

– disconservation of national oil reserves;

– a constructive dialogue with oil and gas supplying countries and with the biggest energy importers to maintain the stability of the global oil market.

The main tools for achieving these goals are legislated tax and financial incentives for alternative energy development and the gradual qualitative change in the infrastructure and energy standards in the country. The scale and the complexity of the problem does not make it less necessary because today's energy dependence of the US on individual countries threatens:

– successful implementation of foreign policy;

– a significant reduction of political and economic importance of the United States in the international arena;

– national prosperity and economic stability;

– the possibility of a critical loss of control of the situation within the country and in the world due to the global energy imbalance.

Dependence on imported energy carriers and environmental safety threat caused an active increase in production and consumption of biofuels. In 2005, the U.S. became the largest producer of ethanol in the world. The composition of ethanol in the gasoline in the US increased in volume from 1% in 2000 to over 3% in 2006 and reached 12% in 2014.

The United States is the largest biethanol producer in the world. This fuel al-lows to make annual savings about $ 1.5 billion of purchasing oil products, ensure stable operation of agriculture, create new jobs through the construction of distilleries and improve the ecological situation. Compared with Brazil, the US fuel ethanol is mainly produced from corn. Today, there are tax incentives for fuel ethanol to make it cheaper than gasoline. The leader for the production of fuel ethanol in the country is Illinois state, where 14 plants with capacity of 8 billion liters per year are located. The annual capacity of all country's bioethanol production plants reaches 64 billion liters. According to the Association of biofuels, in 2011 there were 209 plants for production ethanol in the US, they are located in 29 states, and another 140 were under construction or expansion. Most of reconstruction projects designed to upgrade facilities for improving the economic efficiency of bioethanol production, reducing the energy consumption and improve the quality of by-products.

In the U.S., 96% of gasoline sold at gas stations includes bioethanol in its composition. The main feedstock for bioethanol production in the country is corn. The use of this crop has a number of economic and environmental benefits. Corn provides the highest ethanol output from 1 ton of feedstock – 400-450 liters. The production of ethanol from the corn allows to obtain not only environmentally friendly fuel, but high-quality protein feed. In the US, the amount of feed that are in the production of ethanol from corn is 1/3 of the amount of raw materials consumed in the production of bioethanol. This is linked with the fact that for ethanol production it is nedeed to use only a por-tion of corn (starch) that as a result of fermentation is converted to alcohol. The remaining protein, fat, fiber and other nutrients are used in the future as feed for cattle, pigs and poultry.

In the US fuel ethanol is mainly used as an oxygen additive to gasoline in a mixture with gasoline up to 10% and like a fuel E85 for cars that can run on petrol, bioethanol, or any of its mixes (flex-fuel vehicle – FFV).

Today the USA delivered more than 8.5 million of FFV to the car market. There is a tendency to increase their production. With the advent of these vehicles, respectively, and the number of filling stations (where you can buy E85) in-creases every year.

The federal government provides financial initiatives for biofuels over the past thirty years. From 1978 to 2004, tax credit was introduced for the amount of ethanol that mixed with gasoline for federal taxpayers of excise duty on motor fuels. Over the years, the tax credit varies from 40 to 60% per gallon of ethanol. During 2005-2008, it was 51 cents per gallon of ethanol mixed with gasoline, which was slightly more than 5% per gallon of E10.

From 2009 to the present day the tax credit was reduced to 45 cents per gallon of ethanol. However, the second generation ethanol produced from cellulosic feed-stock will receive a tax credit of $ 1.01 per gallon.

The administration of the Department of the US Environmental Protection determined that second-generation biofuels are considered as any renewable fuels produced from renewable biomass, life cycle greenhouse gas emissions of which is lower at least below 60% than conventional fuel. Thus, the traditional bioethanol produced from corn, cannot get $ 1.01 of tax credit, but cellulosic ethanol produced from corn stalks and cobs (without seeds) may have this privilege.

As a historical example, it tooks ages for bioethanol to fix place in the energy market in the US. Henry Ford constructed his first car model T in 1908, that worked with both gasoline and ethanol. However, a big lag in the cost of gasoline and ethanol postponed the use of ethanol for 70 years, when gasoline prices rose sharply. Then the US Congress adopted the decision on state support of ethanol.

Energy policy of the US Government:

1. Reducing greenhouse gas emissions by 80% by 2050.
2. Investment in alternative energy by 2025 and providing 25% of energy from the alternative energy sourses.
3. Supporting the technology development of second generation biofuels, development of technologies of getting ethanol from cellulose.
4. Reducing the energy intensity of the economy by 50% by 2030.
5. The US global leadership in combating climate change.

In addition, the US government intends to invest $ 10 billion of public investment over the next 10 years to the development of alternative energy sources. The money will create new economic sector and provide at least 5 million new jobs.

Brazil

Sugarcane has been cultivated in Brazil since 1532 as sugar was one of the first commodities exported to Europe by the Portuguese settlers. The first use of sugarcane ethanol as a fuel in Brazil dates back to the late twenties and early thirties of the twentieth century, with the introduction of the automobile in the country.

In 1979, in order to ensure the uninterrupted sales of bioethanol, the government has obliged the industry to issue 350 thousand of vehicles that operate solely on bioethanol until 1981.

After the end of 1980 the number of cars that run on pure ethanol reached more than 4 million, one-third of the fleet of vehicles in the country, the ethanol production and sale of vehicles that run solely on bioethanol decreased by a number of reasons. First, gasoline prices have fallen sharply because of low oil prices. But the main reason was lack of ethanol in the domestic market because thousands of cars were left without fuel in mid-1989. Stocks of ethanol could not provide a growing demand for it because of a large number of vehicles that run only on ethanol, that is why the Brazilian government was forced to start imports of bioethanol in 1991.

The credibility of the vehicles that run on ethanol was restored only with the advent of FFV (flexible-fuel vehicles) on the Brazilian market – the cars with "flex engine" that are able to use fuel from any content of bioethanol.

In 2013, there were such car manufacturers with flexible engine as Chevrolet, Fiat, Ford, Peugeot, Renault, Volkswagen, Honda, Mitsubishi, Toyota, Citroen, Nissan and Kia Motors.

The Brazilian ethanol industry has a tangible difference compared to the bioethanol industry of the US, not only by using different feedstock (sugar cane and corn). In Brazil, there are two types of ethanol that are produced and sold to customers – dehydrated and hydrated (non dehydrated). Dehydrated ethanol, which is a standard in the USA, contains about 0.5% of water in the volume and is blended with gasoline for fuel use. Hydrated ethanol has 5% water content. Today, most vehicles in Brazil, including FFV, can run on E100 – pure ethanol, and any of these two types of compounds.

The production of fuel ethanol in Brazil is based on the most efficient agricultural technology for sugarcane cultivation in the world that uses modern equipment and cheap sugar cane as a feedstock for ethanol produc-tion. Sugar cane is a perennial crop, and can produce up to 7 harvests. This reduces the number of manufacturing operations at its growing, as a result reduces costs and helps to reduce emissions of harmful gases into the atmosphere. Bioethanol produced from sugar cane reduce greenhouse gas emissions by 71%.

The production of bioethanol from sugar cane does not require enzymes to convert starch polysaccharide into fermented monosaccharides, which makes it possible to use a smaller number of manufacturing operations and significantly reduces the cost of production. By-product that is obtained during the processing of sugar cane, the so-called bagasse – fibrous waste from sugar cane, which remains after juice extracting, is used to produce heat and energy that allows you to get a competitive price and high energy balance, which varies from 8.3 in medium terms to 10.2 for the highest efficiency.

European Union

Member States of the European Union are required to achieve at least 10% share of renewable fuels in transport by 2020. Produced biofuels were taken into account in achieving this goal, must meet sustainability criteria stipulated by the Directive on Renewable Energy (Renewable Energy Directive 2009/28/EC) and reduce carbon dioxide emissions into the atmosphere at least by 35% when used traditional fossil fuels.

The main type of biofuel produced by the EU is biodiesel. The proportion of ethanol in 2013 was only 30%.

Currently, there are 71 bioethanol plant in the EU, there were 69 in 2012, but the capacity was used only by 55% of total production capacity. It is expected that by the end of 2015 the capacity will operate at 63% of their total potential.

9.47 million tons of sugar beets and 4.65 million tonnes of wheat and 4.97 million tons of corn were used for the production of ethanol in 2013. Barley and rye in volumes of 540 and 480 thousand tons respectively were also used.

The largest producers of ethanol in the EU are France and Germany.

In France, the first attempt to find alternative energy sources are dating from the beginning of 1980. In the mid 80's, an interest in the production of rapeseed oil for biodiesel started to develop. In 1985, French Petroleum Institute has developed a technology to produce biofuels. In the late 80s the first studies were conducted. In 1990-1993, it has been organized research that was financed by the EU. The real growth of the production and use of biofuels in France was only in the beginning of the 1990s, when the production and use of bioethanol and biodiesel accompanied by large-scale exemption from excise duty.

But the result of such activities was a large volume of biofuel production. In response to overproduction in 2002, it was set the maximum amount that introduced the quota system by which biofuel producers may be exempted from taxation. Quotas for the release of biofuel production are tax adjusted annually, besides its maximum volume is sufficient to fill the financial gap between biofuel and traditional fuel.

To encourage the wholesale traders to add biofuel to traditional fuel, the law of 2005 introduced an environmental tax TGAP (general tax on polluting activities, La taxe générale sur les activités polluantes), which is applied to every cubic meter of sold fuel. The tax rate is corresponded to the percentage of biofuel, which should be added annually to conventional fuels, and applied to ethanol, which is mixed with gasoline, and to biodiesel which is added to diesel fuel. Merchants pay no obligations related TGAP, if they can prove that such biofuel is contained in the amount of fuel they sold.

At present, the support for biofuel producers in France is that the government provides subsidies to its producers and at the same time imposes high tax rates on the fuel producers who do not comply standards for levels of biofuels. In this case they have to pay tax on the amount of non-added biofuels. Thus, the mechanism of supporting and encouraging the production of biofuels is the increase of taxes for manufacturers of traditional fuels and exemption of biofuels producers according to given quotas.

France adopted a national indicative targets for mandatory biofuel content of 2% in 2005 and 5.75% in 2010, which corresponded to the target figures set by the EU Directive on biofuels. French legislation aimed at protecting the environment by combating greenhouse gases and pollutants, later anticipated increase in these indicators over the next years: 5.75% in 2008, 7% in 2010 and 10% in 2015. It means that France plans to exceed two years plans of the European Commission in the field of biofuels, and biofuel production in France is growing every year.

French vehicles consume 75% of diesel fuel (30-35 million tons) and 25% (10-15 million tons) of gasoline. Therefore, for biodiesel manufacturers there is almost no problems. But ethanol producers have to work harder, because some fuel manufacturers believe that it is more profitable to pay the tax for non-added bioethanol to gasoline than to provide the mandatory content of bioethanol.

In France, gas stations sell gasoline that contains 5 and 10% of bioethanol. Such mixed fuels may be fueled by cars produced after 2000 (75-80% of the French cars). The engine of these cars can run on such fuel mixtures without making changes to their design.

Another type of blend fuel is mark E-85 fuel, that consists of 85% ethanol, and 15% –petrol. They can be filled only by specially adapted vehicles.

In addition, France, apart from Italy, is the only European country that applies the bidding system designed to promote international competitiveness through the provision of an international entity to meet the country's current demand for biofuels. In the French tender system, biofuels producers receive an official certificate (valid for 6 years) for the supply of biofuels on their markets. Foreign producers can use the French tax exemptions on excise duty, if they satisfy the conditions of supply to the market.

The main feedstock for bioethanol production in the EU are sugar beets, wheat and corn. The share of sugar beets in the structure of feedstock for processing into bioethanol is 45%.

The peculiarity of bioethanol production plants in France is a combination of capacity in one production site the facilities that can produce ethanol from various feedstocks (such as sugar beets and cereals), and process this feedstock for food in terms of unfavorable market situation.

Cristanol Plant, located in Bazankurt in the east of France, brings together sugar factory, alcohol plant, bioethanol and biogas on one production area.

Cristanol plant produces sugar, bioethanol from sugar beets bioethanol from grain, edible alcohol, biogas from DDGS and animal feed.

The feature of the Cristanol plant is ability to adjust production volumes of certain types of products due to market conditions. So if the market situation is unfavorable for the sale of sugar, the factory direct more feedstock for bioethanol production and vice versa. And thanks to the grain technology of bioethanol production, there is a possibility of stable work of the plant during the whole year.

Biogas production from sugar beet by-products and bioethanol production substantially affects on the energy balance and environmental situation.

The factory is located in the area of sugar beets production in France, because the main task while purchasing feedstock is to provide the transport distance of sugar beet within less than 100 km from field to factory. This is due to the fact that the yield of sugar beets amounts to 100 t/ha, so to transport them over long distances is not economically profitable. In addition, beets rot quickly, so they need to be processed as quickly as possible and not to be kept for long in piles.

The plant runs on beet and cereals. Its annual production capacity is 350 million liters of bioethanol. The plant produces 150 million liters (120 000 tonnes) of bioethanol from sugar beets and 200 million liters (160 000 tons) from cereal.

100 liters of bioethanol can be obtained from 1 t of sugar beets. The average yield of sugar beets in France is 90-100 t/ha. Thus, the plant processes 1.5 million tons of sugar beets to bioethanol from the area of over 16 thousand ha.

The average yield of wheat in France is 8 t/ha. 1 ton of wheat produces 400 liters of ethanol. Accordingly, the plant processes about 625 thousand tonnes of wheat annually from over 78 thousand ha. In order to obtain the feedstock, plan managers make agreements with farmers who are members of the Cristanol Union cooperative. The plant receives feedstock at fixed prices, and farmers are deprived of the problem of finding sales places and simultaneously receive money for locally grown products. Because the Cristanol plant enter into contracts with farmers for the supply of raw materials, it receives products at slightly below market prices. So the plant buys sugar beet at a price of 20-30 euros and wheat at a price of 130-160 euros per ton.

In addition to sugar and bioethanol, the plant produces annually 190 thousand tons of meal (from grain processing to bioethanol) and 375 thousand tons of dry pulp (from sugar beet processing). These co-products are used as high-energy animal feed supplement.

Biogas production from sugar beet by-products and bioethanol production substantially affect the energy balance and environmental situation. Cristanol Plant is working on technology that enables to obtaine 9% of sugar, and the remaining 10% remains in the so-called intermediates between sugar and molasses, which is called «green» molasses. Thus the plant can save a lot of energy.

The final stage of production at the plant is processing and utilization of molasses vinasses. In foreign literature the molasses vinasse and vinasse from the processing of sugar juices and syrups are defined as vinasse. The most common method of processing and recycling vinasse is its compression by evaporation to a dry matter content of 70-75%. Te dry part of the condensed vinasses contains about 50% organic matter.

Condensed vinasse is used as fertilizer for the land where sugar-containing feedstock is growing, in the amount of 2 to 5 tons per hectare per year, depending on soil quality. Thus, the balance of chemical elements in the soil is maintained and the need for fertilizers is reducing.

Efficient way to use molasses or grain vinasses may be its methane fermentation. For this type of fermentation 50-60% of organic matter of substrate can be converted in biogas. Part of the organic matter that remains together with the mineral part comes from the biogas reactor as a liquid, which could be droped into the open water after refining. Schematic diagram of biogas from waste distilleries (vinasse) are shown in Fig. 3.9.

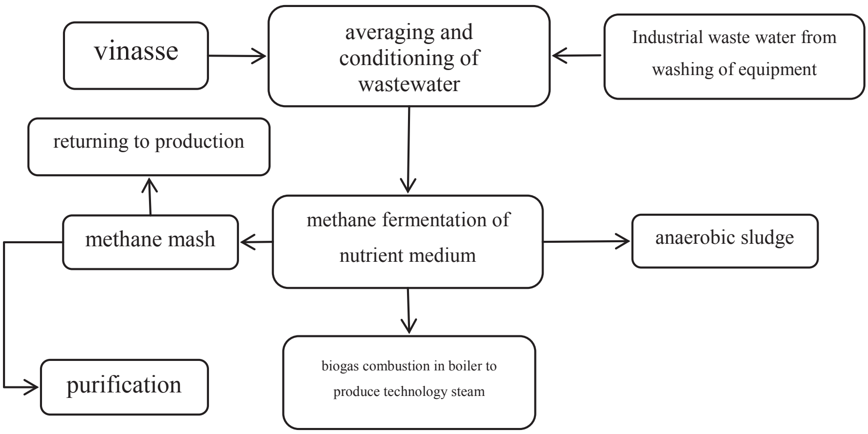


Figure 3.9. The Technological Scheme of Biogas Production from Vinasse

Considering that the production of 1 ton of bioethanol need about 2.3-3.2 t of the heating steam (6.8 GJ of thermal energy), using biogas from the anaerobic fermentation of molasses or grain DDGS, considering heat loss, can cover 50-70 % of production needs.

After harvesting grain, it is crushed. The starch becomes more susceptible to enzymatic hydrolysis. Then, received rough flour is humidified and mixed. Further enzymes of two types are added to the received weight at a temperature of 90°C. At the same time there is a dissecting of viscosity and molecules of starch on smaller connections. The following stage is saccharification. This process leads to release of the glucose which is containing in starch. Further the glucose saturated with yeast is mixed up and passed to fermentation stage. All glucose turns into alcohol. Then there is a distillation, as a result we receive 94% alcohol. However, to add it to gasoline, it is necessary to remove water impurity from ethanol. Ethanol undergoes a dehydration reaction to 99,9% on molecular sets. After that we can receive an end product – bioethanol.

To trace the full process of bioethanol from grain feedstock let's consider, as an example, one of the plants of Tereos, which is engaged in processing of grain raw materials to bioethanol. It is located in Lilboln, 185 km from Paris. The plant processes 820 thousand tonnes of cereals each year, from 100 thousand hectares of crops. During the year the plant can produce 300 thousand m^3 of bioethanol and 240 ths. tons of related products. Production of bioethanol has several successive stages at the plant of Lilboln (Fig. 3.10).

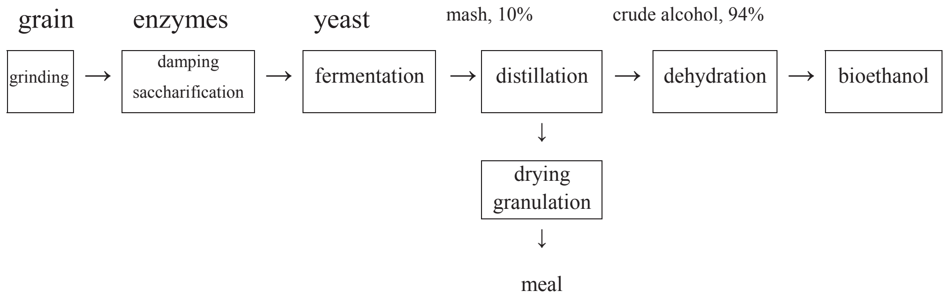


Figure 3.10 Block Diagram of Bioethanol Production from Grain Feedstock

A byproduct of ethanol production is DDGS. It is dividen in liquid and condensed. The liquid is not poured, and added to the crushed flour on the initial stage of production of bioethanol. Condensed vinasse is dried at a temperature of 400°C, then it is used for forming the pellets with a diameter of 6 mm. These granules contain 32% of proteins and is ready to be used as animal feed. Thus, in France 1 ton of wheat can produce 375 liters of bioethanol and 310 kg of dry vinasses.

Waste streams around the plant comes to cleaning drains of fermentation plant with such force that it could recycle waste water of the city with a popu-lation of 250 000 people. The plant is equipped with fermentation units that ferment biogas, which can be burned later to produce electricity.

Overall, production and use of bioethanol in France are developing rapidly. This is contributed to the need to implement the terms of the Kyoto Protocol, the EU directive on mandatory ethanol content in gasoline composition, financial support of producers and the state regulating tax legislation. But France needs some changes in the agricultural sector to expand the area of land allocated for growing biofuel crops, or search feedstock exporting countries, which will help to achieve the national targets on biofuels in the coming years.

Germany

The production of bioethanol in Germany was 672,000 tons in 2013, 40% of the total production in the EU. The feedstock for the production were cereal crops (405,000 tons of bioethanol) and sugar beets (267,000 tons of bioethanol). The share of sugar beet used for the production of ethanol in this country is growing every year. 10 plants produce bioethanol, and are located in the areas of crop cultivation.

Bioenergy policy of Federal Ministry of Food, Agriculture and Consumer Protection of Germany (BMELV) has the following purposes: climate protection and the environment, sustainable and reliable supply of raw materials, maintenance and creation of jobs, particularly in rural areas, high efficiency power supply, the development of technology with export potential.

To implement these goals, it has been created the Competence Centre for Renewable Raw Materials. The main task of the Centre is to conduct basic research and applied research in growing of energy crops that can be used as feedstock for biofuels, expansion and popularization the possibilities of using renewable raw materials, initiating the creation and study of new technologies and products together with the project partners, coordinating cooperation between the sectors of science, industry, agriculture and politics.

Competence Centre for Renewable Raw Materials brings together three organizations: Straubing Science Center, Center of technology and assistance, C.A.R.M.E.N association. In addition, within the jurisdiction of the Centre, 5 research institutes are combined, their objectives are:

– Providing academic education in the field of renewable energies;
– Research and development in the field of biofuels.

At the Center for Technology and assistance, there are applied research, especially in the area of crops, solid fuels for heat and liquid biofuels.

C.A.R.M.E.N. engaged in the dissemination of information among the public and the markets about the possibilities of using renewable resources.

According to the field of use, renewable raw material in Germany can be divided into two groups: for food purposes (starch, protein, oil), consumer use (furniture, paper) and for processing into biofuel for energy purposes (solid, liquid and gaseous).

There are such liquid biofuels of the first generation: biodiesel from vegetable oil, pure oil with no additives, ethanol (from sugar or starch), biogas.

Second-generation biofuels are under research and development (bioethanol from straw and through evaporation). They are called BtL fuels. BtL is defined as Biomass-to-liquid and GtL (gas-to-liquid), Ctl (coal to liquid). They are synthetic fuels, the composition of which meets the requirements of modern engines. The production of BtL fuel can use feedstocks, ranging from agricultural waste such as straw and wood waste and ending with power plants that are specially grown for biofuel production.

EU Directive (2009/28/EG) set the share of renewable energy in final consumption by 2020. At EU level, the share of renewable energy will be 20% of the total, at the level of Germany – 18% of total energy, at the level of each EU member state – 10% in the transport sector.

Federal Government has developed an energy concept which defined the future performance of renewable energy particles in the structure of the fuel and energy complex. Till 2020 the share of renewable energy in total energy consumption will be 18%, 30% of them will account on renewable electric energy, 14% on heat energy, and 10% on biofuels (tabl. 3.11).

Table 3.11

Increasing the Share of Renewable Energy in German Total Energy System, %

Indicators	2005	2006	2007	2008	2009	2020 (plan)
The share of renewables in total energy consumption	6.6	8.1	9.8	9.5	10.1	18.0
The share of renewables in total electricity consumption	10.4	11.7	14.2	15.1	16.1	>30.0
The share of renewables in the consumption of fuel	3.8	6.3	7.2	5.9	5.5	10.0
The share of renewables in final power consumption	5.4	6.1	7.6	7.4	8.4	14.0

By 2050, the Federal Government is going up to 60% renewable energy (Fig. 3.11).

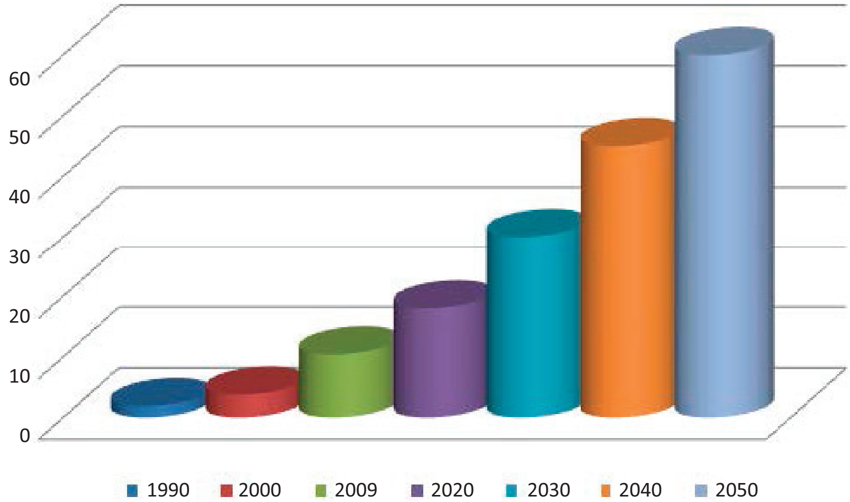


Figure 3.11. Federal Government's Energy Concept on Current and Future Share of Renewable Energy

In Germany, the Law on quotas for biofuels came into force on January 1, 2007. An important aspect of this regulation was that the oil industry was obliged to pro-duce and sell certain minimum of fuel (quota) in the form of biofuels. For the period 2010-2014 this quota is 6.25%. Implementation of the quota may be in the form of admixture of biofuels to fossil fuels and as pure biofuels. Since 2015, the quota for biofuels energy has transferred from the current evaluation option to reduce green-house gas emissions. Subsequently, it is planning to introduce an energy tax, the amount of which will depend on the composition of consumption and CO_2 emis-sions during its use. Then those who use fossil fuels will plan more, and those who use biofuels will plan less. This will serve as a lever to reduce fossil fuel consumption.

3.4. Production of Bioethanol from Sugar-Containing Feedstock

Production of ethanol from molasses includes such basic technological stages:

– Molasses preparation for fermentation;
– Preparation of pure yeast culture;

– Growing industrial yeast;
– Fermenting wort;
– Distillation and concentration of alcohol;
– Dehydration of alcohol.

Scheme of material flows in the production of ethanol from molasses shown in Fig. 3.12.

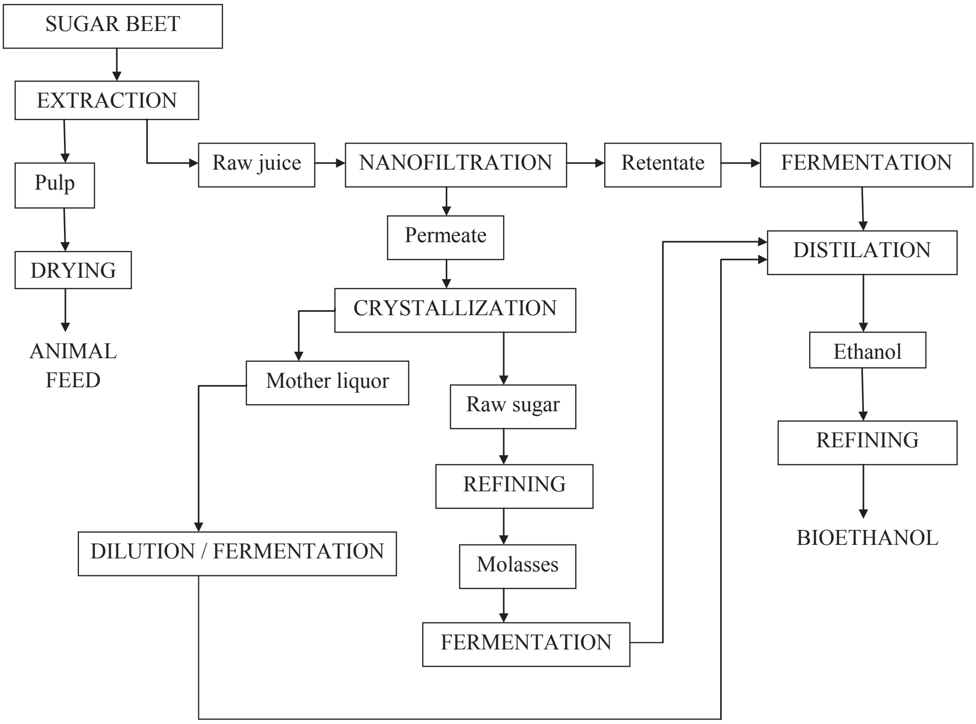


Figure 3.12. The Basic Technological Scheme of Production of Bioethanol from Molasses

Preparing for molasses fermentation

The composition of molasses depends not only on the technology of sugar production, but also on the farming techniques of growing, storing beets and others. Molasses is placed by layers in shelters. Therefore, before starting the production, it must be mixed to obtain a homogeneous mass.

When the molasses is receired in the production, an average sample is taken, which determines the main indicators (sugar content, pH, acidity, alkalinity, solids, invert sugar, raffinose and goodness). If signs of defects detected, various technological means are used to correct them, such as feedstock preparation mode.

The process of fermented molasses preparing has the following operations:
– Heat treatment (pasteurization, sterilization)
– Chemical antiseptication;
– Acidification;
– Enrichment of nutrients;
– Preparation of molasses wort.

Heat treatment of molasses

A large number of microorganisms is preserved in the molasses that can multiply rapidly in favorable conditions. Their metabolic products violate the process of fermentation, and caused the loss of sugar, quality degradation of alcohol and baker's yeast.

To decontaminate molasses, it is treated accordingly. One of the effective ways is the method of heat treatment of molasses (sterilization or pasteurization).

The thermal sterilization treatment is performed by heating of molasses with steam of heat exchangers at the temperature of 100-110°C and is held at this temperature from 1.5 to 2.0 minutes. Thereafter, the molasses is fed to a collec-tion and cooled to 35-40°C.

Pasteurization of molasses, in contrast to sterilization, occurs at a temperature of 85-95°C and exposure time is 60 minutes.

Acidification of molasses

One of the important operations to prepare molasses fermentation is acidification with inorganic acids (hydrochloric or sulfuric).

The aim of molasses acidification is to achieve optimum value of pH for creation the yeast breeding and alcohol fermentation process of molasses wort. Additionally, acidification inhibits infecting flora in molasses.

In order to ensure stable output of ethyl, during alcoholic fermentation the wort is acidified to pH 5.0-5.2 (for single-branch) and to the value of pH 4.7-5.0 (dual-branch method for fermentation).

Increasing the pH value over the optimal value leads to increasing the costs for sugar formation of by-products of fermentation and to minimize alcohol output. Lowering the pH of the environment reduces the synthesis of yeast and slows down the fermentation process. Acidification of molasses promotes the enhancement of antiseptic force.

Acidification of molasses with inorganic acids

Sulfuric or hydrochloric acid are used for acidification.

The total acid expenditure for acidification of molasses consisting of acid needed to neutralize the alkalinity of molasses and acid creates wort optimum pH value and acidity. Calculating the cost of sulfuric acid is perfomed with the monohydrate content in acid, and hydrochloric acid and lactic is perfomed with the contents of output acids.

The estimated amount of acid is diluted with water in 4-5 times and contribute to each weight of molasses. The dilute of acid with water takes place in the acid-resistant devices. For uniform distribution of the auxiliary materials dosed in molasses, stirring is operated with mechanical mixers.

In a single-commodity production (molasses fermentation to make ethanol), only that portion of molasses that incomes for wort preparation is acidified and antisepted. Acid is made based on all the molasses and held for 6.8 hours.

Molasses antiseption

The heat treatment of the molasses needs a lot of energy resources. So in practice of alcohol production, in order to fight molasses infection, chemical molasses antiseptics of origin nonacidic nature with antimicrobial and disinfectant properties is often used. Antimicrobial drugs that are used in alcohol production must have a high bactericidal effect, but do not affect negatively on the life of yeast.

Acidification of molasses is not sufficient to prevent the infectious microflora. Therefore, antiseptics are used for all amount of molasses (bleach, sulfanol). The essence of the chemical antiseption of molasses is maintaining its withstanding with antiseptic at least 8 hours.

Chlorinated lime is introduced in the form of molasses in the preformed aqueous extract at a ratio of bleach to water as 1 : 10.

After mixing the bleach with water, solution is sludged for 18-24 hours, decanted and introduced into the molasses and the rate of 0.5-0.6 kg per 1 ton of normal molasses. If the infection rate of molasses exceeds the standards, the amount of bleach is increased to 1.2-1.5 kg/t of molasses and kept it with bleach at least 6-8 hours.

Sulfanol belongs to the group of surfactants, inhibits the development of acid-forming bacteria and has no effect on the livelihoods of yeast, and its bactericidal effect keeps molasses and molasses wort for 10-15 days.

Antiseptic sulfazol (70-100 g per 1 t of molasses) destroys only acid-forming flora, so to improve antiseption it is used together with chlorine bleach in 1: 1 ratio.

Desactin is an antiseptic preparation revealing its antibiotic bactericidal activ-ity in an amount of 100 g/t of molasses.

Frikont is an antiseptic preparation in quantities of 1 g/t molasses revealing a bactericidal action against microorganisms of molasses.

All antiseptics are carried in as aqueous solutions at the appropriate instructions.

Preparation of nutrient solutions

Alcohol plants use nutrients (salt) in the form of aqueous solutions with specified concentration. The concentration of solutions can be mass, volume and combined (mass-volume).

The mass or weight of concentration (ρ_i) is a mass of salt dry matter in relation to the weight of 100 kg of aqueous solution in percentages, and in kilograms of the substance per 100 kg of solvent (water).

The mass-volume concentration (***C)*** is a mass of salt dry matter in the unit of solution volume in kilograms per cubic meter, in grams to cubic decimeter.

The volume concentration (v) is the volume of any liquid, such as alcohol, in 100 of solution volume (dm^3/100 dm^3). Formulas for calculating of concentra-tions are given in Table 3.12.

Table 3.12

Formulas for Calculating the Concentrations of Solutions

Concentrations	$\rho_{i,}$ %	$\rho_{i,}$ g/100 g	*v, g/dm*^{3}
Mass (per 100 g of solution)	ρ_i	$\frac{100 \cdot \boldsymbol{\rho_i}}{100 + \boldsymbol{\rho_i}}$	$\frac{v}{10d}$
Mass-volume (per 100 g of water)	$\frac{100 \cdot \boldsymbol{\rho_i}}{100 \cdot \boldsymbol{\rho_i}}$	C	$\frac{100 - v}{1000d - v}$
Volume	10d· ρ_i	$\frac{1000d - C}{100 + C}$	v

The concentrations of salt solutions are measured with hydrometer.

If we know the salt weight *G* in kilograms, concentration *K* and salt solution density *d,* we can determine the mass of the solution *m* in kilograms, the volume of the solution *V* in cubic meters using the general formula:

$$m = \frac{G \cdot 100}{K}$$

$$V = \frac{m}{d} = \frac{G \cdot 100}{K \cdot d}$$

Using formula 2 we can determine the weight of the salt (G) in kg in the solution:

$$G = \frac{VKd}{100}$$

On the basis of these equations, the correlation between different methods of displaying of concentration of salt solutions, such as for the preparation of diammonium phosphate solution is determined. The solution is given in three ways.

Method 1. Using the mass concentration (per 1000 kg of solution). To prepare the solution with 20% concentration, 200 kg of salt is weighed and 800 kg (dm^3) of water are added. The weight of the solution is equal to 1000 kg and its density is 1117 kg/m3 (1.117 g/dm^3). Thus, the volume of the solution in cubic decimeters is determined by the formula

$$\frac{G \cdot 100}{K \cdot d} = \frac{200 \cdot 100}{20 \cdot 1.117} = 895 \text{ or}$$

$$V = m : d = 1000 : 1.117 = 895$$

Method 2. Using the mass concentration (per 1000 kg of water). Calculation is carried out on proportions: 200 kg of salt – 800 dm^3 of water, 1,000 dm^3 (kg) of water – (200 • 1000): 800 = 250 kg of salt.

The same results can be obtained by using the formula of calculated concentrations:

1 kg of salt per 100 kg of water

$$\boldsymbol{\rho_i} = \frac{100 \cdot}{K \cdot d} m : d = \frac{100 \cdot 20}{100 - 20} = 25$$

or 250 kg of salt per 1 m^3 of water.

Solution mass m=250+1000=1250 kg.

The volume of solution

$$V = \frac{250 \cdot 100}{20 \cdot 1.117} = 1119$$

Method 3. Using the mass-volume concentration (1,000 dm^3 of solution). To prepare the 1000 dm^3 of solution with concentration of 20% dry matter, we must weigh not 200 kg, but 1,117 · 223,4 kg of salt and bring the volume up to

1000 dm³. The mass in kilograms of salt in cubic meters is calculated with the formula 3.3:

$$G = \frac{VKd}{100} = 223.4$$

According to the formula of calculated concentrations we get the same result in grams in a cubic decimeter:

v=223.4 kg per m³

Thus, in order to prepare a solution concentration of 20% of diammonium phosphate, there should be 200 kg of salt, 800 dm³ of water or 250 kg of salt and 1000 dm³ of water, or 223.4 kg of salt to bring water to a volume of 1000 dm³.

Among three following ways preparation of solutions we should choose the most appropriate and use this method to make calculations for solution of any salt.

Molasses wort preparation

Molasses contains 75-80% of solids. The last consisting of sugars and non-sugars. With such a high concentration of solids it can not be fermented by yeast, so antisepted molasses is diluted with water to a concentration of solids of 20-28%, depending on the method of fermentation. The number of molasses and the amount of water required for the preparation of wort, are calculated based on the equation of balance of dry matter, which is as follows:

$$\frac{G_m CP_m}{100} = \frac{V_c \cdot d_c \cdot CP_c}{100}$$

Obtaining the mash with necessary concentration of homogeneous solids is a prerequisite for maintaining the stability of the yeast life and biochemical processes of ethanol formation.

In the condition of continuous production, sugar or molasses wort is prepared in continuously operating mixers. Mixer, designed by USRIEP, is a vertical cylindrical vessel, the bottom of which has installed pipes for the supply of molasses, hot and cold water pipe and faucet for washing. The circular comb is attached directly to the bottom, forming a chamber, which summarizes molasses and hot water. The connection for cold water is installed tangentially to better mixing molasses and hot water out of the lower chamber. Piping hot water ends and toothed notches rest on the bottom of the mixer.

The mesh plate is set at the top of the mixer. Each plate has a cutout that is located on the opposite side. The area of cutout section is equal to area of pipelines. In addition, the plate has holes 24-25, 15-20 mm. Volume of the mixer is calculated based on the needs of its being in the solution for at least 15 to 20 seconds.

Cultivation of yeast

Bioethanol is a product of deep decay of sugars that is carried out with yeast cells and is called fermentation.

The nutrition of yeast cells is conditionally divided into two phases: the first phase is characterized by substances passing through the cell membrane, the second is characterized by occurring the complex reaction processes of assimilation and dissimilation. Yeast belongs to heterotroph organisms. For this substance, metabolism is based mainly on nutrition of prepared organic substances. Glucose and fructose are fermentable directly, but the yeast used in the production of alcohol can ferment maltose efficiently, formed by the hydrolysis of starch and sucrose (which is part of beets, beet and cane molasses) and invert sugar.

The first and basic property of living cells is the ability to reproduce themselves with the utmost precision. The second feature of the cell is its ability to metabolism and the implementation of a large number of chemical reactions. These two features are interrelated and interdependent. Vital functions of the cell, and their existence are not possible without a large number of intercommunication of various intracellular biochemical changes, which are based on the specificity of enzymatic catalysis.

The yeast life activity is defined as the ability to adapt to external conditions. The link between yeast cells and nutrient, the adaptation to it and its changes according to their needs, create favorable physicochemical conditions and determine the activity of enzymes of additional synthesis, accelerate intracellular biochemical conversion, which are necessary for the process of gemmation.

When considering the patterns of reproduction and cell growth, we use such definitions as yeast cell growth speed by investing in these definitions the rate of formation of cells or biomass.

Increasing the number of cells indicates yeast breeding, and their sizes tell us about their growth. At periodic manner of culturing, yeast propagation velocity has the following growth phases. Yeast cells do not begin to multiply immediately in a liquid nutrient medium, but subsequently. During this period, cells adapt to the environment, act on it by enzymes and convert the complex components into simple that are able to diffuse into the cells.

The length of time during which the yeast cells have not begun to breed in the environment yet is called the lag phase.

After a lag phase cells start to grow, increasing their size, forming the buds – this is a start of yeast breeding. After a period of time, called the duration of the generation, the number of cells and biomass are doubled. During this period the yeast propagation has a constant specific speed. The number of cells and their mass increase exponentially. The period of rapid cell division is called a logarithmic or exponential phase, because the equation that describes the relative speed of propagation of culture, the amount of time stands in the exponent. If the number of cells or biomass expressed in logarithms, the dependence of the rate of cell mass occasionally is portrayed sloping straight line.

In this period, cells are the most active, young, and are budding fast. With environment weariness, the yeast propagation is slowed down, cell growth is decreased – there is a slowdown phase, also known as the phase of negative acceleration of growth. This percentage rate of reproduction is gradually reduced.

The yeast reproduction is completely stopped with decreasing of medium nutri-ent content, and reached the stationary phase. The number of cells and biomass are not changed. The entire cell population is in the final stage of development.

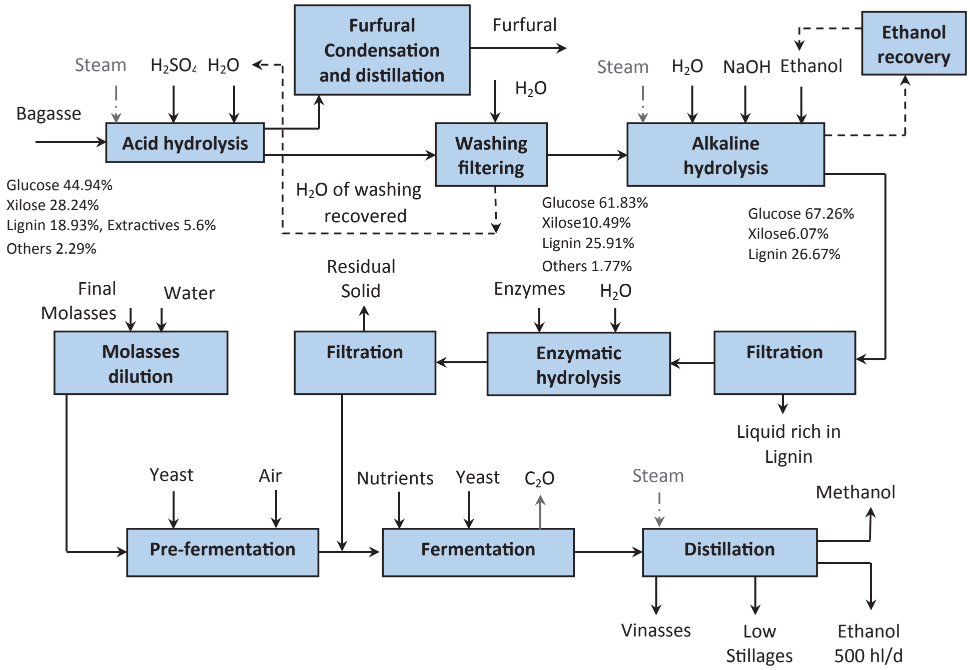


Figure 3.13. The basic technological scheme of ethanol production from molasses

Later the number of cells and biomass starts to decrease. Having exhausted nutrient medium, the cells use their own backup material to maintain life. There comes a phase of aging and dying of culture under the influence of metabolites and autolytic processes that accompanied the disintegration of cells. All this leads to the decrease of biomass and growth curve goes down.

Figure 3.13 shows a fundamental technological scheme of producing ethanol from molasses at sugar-ethanol company Cristanol Plant (Bazankurt, France). This company produces rectified alcohol or alcohol raw (99.8%) together with the usual dehydrated alcohol. Azeotropic rectification with cyclohexane and dehydration modern technology on molecu-lar sieves is used for dehydrogenation. Alcohol vinasse with a mass frac-tion of K_2O about 6% is used for irrigation of fields under sugar beet or as syrup for cattle feeding.

Vinasse is concentrated in several stages. First, there is the department of pre-liminary concentration of 4 to 10%, then the department of final concentration in three stages – 10-27%; 27-37%; 37-70% of dry matter.

Due to the presence of sulfuric acid, potassium sulfate is removed from vinasse in the form of crystals on the centrifuges. Technical denatured alcohol is pro-duced together with technical dehydrated alcohol.

3.5. Production of Bioethanol from Starch-Containing Feedstock

Starchy grain feedstock is used for bioethanol production, mainly in countries with developed agriculture, first of all, in the US, China, Canada, France, Germany, Spain.

The most common feedstock for the production of grain ethanol is corn, wheat, barley, and triticale. Fig. 3.14 shows the basic technological scheme of bioethanol production from grain feedstock.

The technological process of biofuels production from grain feedstock can be divided into two stages. At the first stage of the process the corn grain is purified from admixtures and crushed. In the preparation for processing corn into bioethanol, it is milled in dry or wet manner. After dry grinding, which is often used for wheat and barley grains, refined mass is exploited in hydrolysis and fermentation. After wet grinding the resulting mass is separated into fractions: starch, gluten, and fiber. In turn, the starch fraction is divided into two parts, the smaller is used for the hydrolysis and fermentation, and the bigger is used for food products.

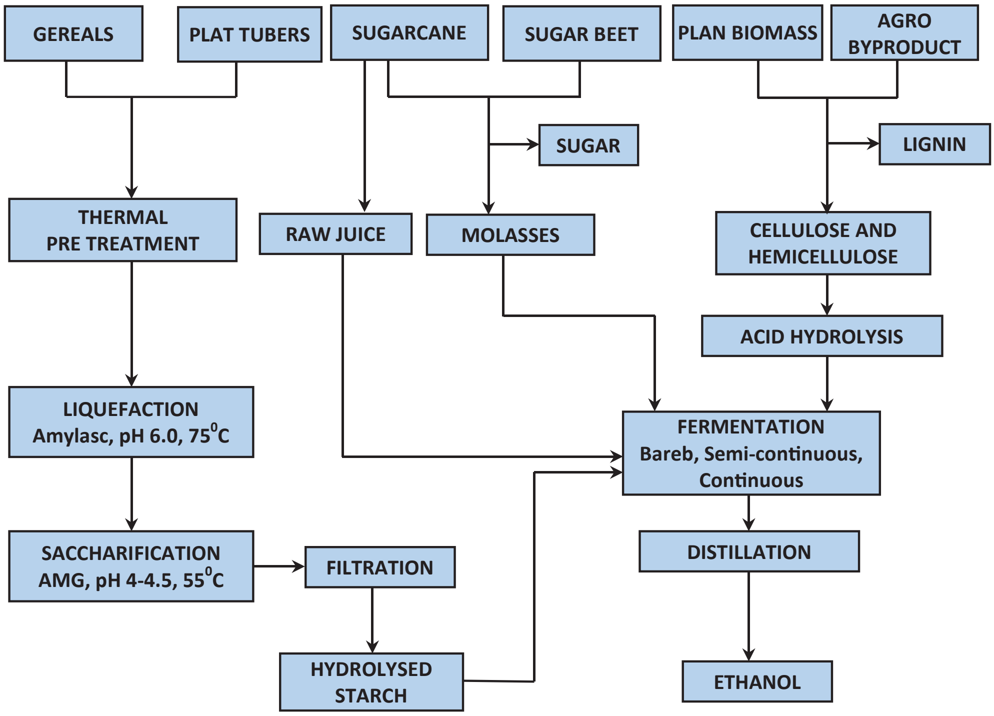


Figure 3.14. The Basic Technological Scheme of Ethanol Production from Cereals

By wet milling, corn germ is separated from them and pressed oil of high nutritional value. Dry grinding produce 33 dm^3 of bioethanol and 27 kg of feed from 100 kg of cereals. The use of wet grinding allows to obtain 36-38 dm^3 of ethanol, 20 kg of feed, 4 kg of gluten and 2 kg of corn germ oil from 100 kg of cereals. Increasing the amount of ethanol that is obtained through wet grinding can be explained by best usage of cellulose and equals about 9.5% of dry weight of cereals.

Kneading is engaged in hydro-enzymatic treatment with enzyme preparations. They contain a thermostable amylase, which allows the process of starch preparation at the temperature that is not higher than 90°C. This technology reduces heat loss at this stage by 30-35%. Original technology of non-hydrolysed starch fermentation by mixed culture of microorganisms is designed. Here, the process of saccharification and fermentation of starch to alcohol takes place simultaneously, making it possible to reduce the amount of commercial enzyme preparations at 90% and accordingly reduce the cost of bioethanol.

In order to fermentate the wort we can use a new yeast strain which has an increased alcohol forming capacity and osmophilic properties. Strain allows to accumulate up to 15% vol. of ethyl alcohol with regulatory output of product per unit of feedstock.

Fermentation usually lasts 48-72 hours. The process of wort fermenting is continuous or periodic with partial evacuation, which increases the strength of the conditioned mash to 18-20% of vol., reduces DDGS volume by 40% and increases the solids concentration in DDGS.

New, effective biocides are used to prevent infection of the wort and mash foreign microflora and improve the efficiency of the use of hydrocarbons.

The guaranteed rate of mature mash is 12-13% content of alcohol.

The second stage of the process is carried by mash distillation, concentration and dehydration of ethanol.

The mash column with concentration part and the relevant part of the heat exchanger and auxiliary equipment is used for obtaining mash distillate.

The fermented grain mass, so-called mature mash, is fed to a distillation apparatus. Here, the crude alcohol is distilled off from it by using the difference of boiling points of alcohol (78,3°C) and water. The crude alcohol contains only 88-94% of alcohol by volume, and the remnant consist of 40 fermentation by-products.

The mash is heated, degassed and distilled and obtain the mash distillate with an alcohol concentration not less than 92%.

The next phase is to separate the alcohol from the residue by distillation and re-distillation. Conventional methods of rectification of crude alcohol cannot ensure completely removing of water because ethyl alcohol (95.57% of weight) and water (4.43% of weight) form a mixture, and its compose will not change the further distillation. A characteristic feature of the mixture is its ability to change the composition under the effect of high pressure water and ethanol exfoliation.

Among various methods of dehydration of alcohol the most common method is azeotropic distillation with added elements (benzene, cyclohexane). This mixture forms ternary solution together with water and alcohol, and it boils at a lower temperature that allows the separation of anhydrous ethanol.

During alcohol dehydration, some installations are used, they consist of a dehydrating column that separates azeotrope and set of dephlegmators, condensers and coolers. Dewatering operation is energy-intensive and high-value process. Today, it is replaced with modern methods of membrane separation.

Ethanol output from raw materials is usually calculated as ethanol output per ton of fermented carbohydrates in terms of starch.

100 kg of hexoses can produce 51.14 kg of anhydrous ethanol and 48.86 kg of carbon dioxide. Based on the relative density of ethanol d420 = 0.78927, his theoretical output is about 64.79 l.

If sucrose is fermented, then 100 kg of this disaccharide (according to the equation

$$C_{12}H_{22}O_{11} + H_2O \quad = 4C_2H_5OH \quad + 4CO_2$$

can produce 53.82 kg (68.2 liters) of ethanol.

The theoretical ethanol output from starch increases in proportion to the ratio of the molecular weight of the polysaccharide and glucose

$$(C_6H_{10}O_5) + (n-1)H_2O \quad = nC_6H_{12}O_6,$$

i.e. 100 kg of starch can make 64.79 kg or 71.98 liters of ethanol output.

During fermentation 1050 kJ of heat is released per kilogram of produced ethanol.

In the production process, fermentable carbohydrates are consumed not only on the formation of ethanol but also to the formation of yeast biomass and by-products of alcoholic fermentation – aldehydes, higher alcohols, esters, glycerin acids.

1.5% of fermented carbohydrates and about 2.5% of glycerol are spent typically while the synthesis of biomass. The costs on formation of supporting products of fermentation depend on the race of yeast used in the production, output wort concentration, temperature and the pH in the fermentation process.

3.6. Obtaining Biogas from Bioethanol Production Waste

Natural resources are used rather unwise in the production of alcohol and bioethanol in Ukraine. The production process is not always effective, and/or by-products with a high residual value remain unused. It is necessary to implement technologies to reduce local and global environmental pollution that will improve indicators of economic efficiency.

Firstly, biogas plant energy consumption compared with modern instalation is above average. The use of heat is step forward, however, the low-cost measure that is quickly amortized. The potential cost is quite significant with concerning of typically high energy consumption in the production of alcohol.

Secondly, it has been offered the instant recovery of waste vinasse, fermentation residue after alcohol distilling, which is a prerequisite for environmental protection. Today, a large number of vinasse is not processed and stored in open lagoons or thrown directly onto farmland. Stored in lagoons waste emit large amounts of greenhouse gases, including methane. Placed on agricultural land vinasse has the fertilizer effect. However, it does not matter whether this happens evenly throughout the year, whether in large quantities, this leads potentially to leaching of nitrates to groundwater or atrophied related environmental systems.

Thirdly, both ways of waste recycling that are currently used in practice, leave the energy potential without vinasse, because it is an energy riched byproduct, which should not be neglected. Usually vinasse output is 1:12 to mass of pro-duced alcohol. All nutrients are remained in the grain vinasse, except the starch which is converted into alcohol while carbon dioxide is released in the fermentation process. Therefore, it is suitable for further use. The vinasse can be used potentially for energy purposes and for animal feed.

Its rationale use is associated with installation of biogas plants for the use of vinasse, which is formed after alcohol fermentation. So, organic biomass share in vinasse is reduced. Vinasse, produced in biogas plant, contains much less organic matter. In addition, organic particles are a common stabilizing material. It means that methane creation remains low, even in the final preservation in open lagoons, which usually creates anaerobic environment. Produced biogas will be used as a replacement for fossil fuels.

Now we have to consider a special vinasse fermentation process at the Cristanol Plant.

Applied principle is based on the innovative high-efficiency vinasse fermentation. Required time for fermentation is significantly reduced due to the biomass inverse movement and any parts that create different conditions of vinasse distribution in the reactor. The concept of the installation has been successfully tested in a pilot scale, although industrialized one has not been introduced yet.

Based on a very high load capacity (10 kg oTS/m3/d) and a smaller period of vinasse being in the reactor (6.5 days compared to thirty days in the reactor with mechanical mixing), the necessary volumes of fer-mentation reactor are much smaller. Fermentation occurs in the thermophilic temperature range. In the technological concept of installation, the fer-menter is connected with biomass separator, which prevents concentra-tion. Enriched biomass is fed again into the fermenter. The process can be stabilized according to the manufacturer's instructions and only through additional substances. The costs for these substances are 10 euros per 500 kWh per day.

According to this concept of installation, the common process of fermentation of solids is not possible immediately, as it increases the concentration of the substrate, as well as liquid atribute and vinasse excreation.

As the reactor cannot be equipped with a gas cap, there should be a separate gas storage with the purpose of gas supply disconnection from the ethanol plant.

Use of sequencing batch reactor (SBR)

The principle of Hager und Elsasser Company (like a version of Cristanol Plant) involves methane vinasse fermentation.

This process is done with the use of SBR and can be provided by quasi-continuous loading with mixing phase and separation phase at the end of the process. After a 6 hours lasting cycle, the liquid fraction will be removed from the reactor and transported to these two fermenting, where it will be processed in similar way. The filed biomass is separated and enters to the first fermenter in the reactor of digested sludge concentration (residue accumulation reactor). Due to the biomass inverse movement, its necessary residence time in the reactor is decreasing.

However, the necessary volume is much smaller than the process in the boiler with mechanical mixing, but still larger than the process used by Cristanol Plant. The functionality of both processes depends on the separable feature of fermented vinasse.

Separation with increasing of the liquid phase

Accumulated vinasse shoud be distributed to the solid and liquid substances. After separation, the share of suspended (separated) solids should be less than 4 g/l because it is a prerequisite for treatment in UASB-reactor. This process depends on two factors. On the one hand, the quality of separation should allow the use of separate liquid phase in the reactor. On the other, there should be available feed market, which could sell the separated solid phase.

The separated liquid phase will be treated in UASB-reactor. In contrast to other types of reactors, in this case biomass enrichment is taken place in the reactor. There will be the flow with the speed of approximately 1 m/h from the ground and over the reactor. In sewage flow, there has been created so-called "beads", or bacterial conglomerates. At the top of the reactor (usually with a height of 4 to 5 m) stiff sheet iron is located, which prevents the release of bacterial mass and stimulates smoking of pellets. In such reactors, load capacitances can be up to 10 kg CSB/m^3 per day. The range of time is 3.5-4.5 days.

At the same time, the required volumes are reducing. As received heavy fibers are separated before entering the reactor bards, there will be higher levels of biomass and fermentation time will be reduced.

3.7. Perspective Directions of Bioethanol Production and Use in Ukraine

The increasing cost of traditional energy sources, the growing shortage of energy resources and the negative environmental impact of fossil fuel consumption are the main driving forces that cause constant growth of biofuel production worldwide. For further development of the economy, in accordance with international standards, the development of bioenergy is too important for Ukraine. At the present stage of state development the production of biofuels is one of the main catalysts of new global trends in agroindustrial complex of Ukraine. This is due to the reduction of mineral reserves, the country's high dependence on oil imports, changes in the structure of agricultural production, the constant growth of price disparity in the energy, industrial and agricultural products.

Ukraine with a strong natural resource potential for growing biological feedstock should move from an export-oriented agriculture in the cultivation of energy crops with a view to further processing of biofuels in the country.

The most promising for ethanol fuel production in Ukraine are crops and products of their primary processing with a high sugar or starch containing,such as corn, cornmeal, sugar and grain sorghum, sugar beet, waste and by-products of sugar production, such as molasses, the amounts of which is about 2 million tons per year. Potatoes and special industrial crops also can be used as the feedstock for fuel ethanol production.

The analysis of the structure of sown areas and the balance of grain allow to suggest that the projected level of crop production in the future is sufficient for food and for the production of a certain amount of biofuel.

The energy independence is a very important strategic goal, because Ukraine has already felt the manifestation of energy dependence. There is a need of very d ifferent approaches on the issue of renewable energy.

Europe has begun to solve the renewable energy challenges when biofuel was more expensive than traditional sources in ten times. And there is no hope that the oil price will decline. Therefore, expansion of acreage under maize, rapeseed, soybean, sugar beet, oilseed flax with simultaneous development of innovative technologies for their cultivation is a solution to the problem of stable production of biological feedstock for the development of biofuel market in Ukraine.

Experts argue that there is no need to build new plants for the production of bioethanol. It is necessary, first of all, to convert part of the distilleries and learn the technology of complex processing of biological feedstock, and then the country will be able to ensure compliance with the Directive of the united Europe. Our near perspective is to attract the investment for commissioning distilleries, oil processing plants, develop their own zone of growing the necessary crops. The same conditions can be created for domestic and foreign investors. Commissioning of these facilities will create thousands of new jobs, own raw material base will be used on production of biofuels. Ready products will satisfy the demand of the domestic market and can be exported.

Attracting foreign capital is desirable, since foreign companies have experience in the production and the formation of the biofuel market. Perhaps the oil companies can be statutory forced to add ethanol and biodiesel to the fuel. Anticipating the resistance of oil traders, the US reduced the excise tax on gasoline mixed by 13.5 cents, which is certainly advantageous to the oil companies. It is clear that there should be a benefit from all links in the closed production chain of biofuels, in other words, to make it profitable for oil companies, agricultural producers and those who produce biofuels.

Now there is crisis in sugar beet subcomplex in Ukraine. Producers of sugar beet and sugar have negative effects of the crisis, so these problems of agricultural sector will be exacerbated in the future.

At the present stage it is necessary to improve the new technology of cultivation, harvesting and pre-treatment of raw materials. It differs significantly from the developed countries.

Such institutions as Plant Production Institute named after V. Ya. Yuryev of NAAS, oilseeds, Ivano-Frankivsk Institute of agroindustrial production of NAAS conducte the research on improving the genetic potential of energy crops that are suitable for processing into biofuel. In the next few years, new hybrids and varieties of energy crops, the latest technology of biological crop cultivation will be tested, which should be used in predicting the increase in volumes of production of alternative fuels.

The analysis of the current market of energy equipment and industrial bioetha-nol production technologies in Ukraine proves that technically there are no significant barriers for the production of bioethanol. The economic effect of ethanol production will grow, as evidenced by the research, in terms of optimal choice of technology of cultivation and processing-based approach to reconstruction or construction of processing plants in places of feedstock storage, as well as comprehensive maintenance of its processing.

When you create a bioethanol plant, there shoud be minimized energy costs, as related impurities in the fuel ethanol have no fundamental significance. In the countries where the production of bioethanol is sufficiently developed, the grain is processed using integrated technologies. They provide the allocation of protein and fat from the grain before using its starch component in the bioethanol production. Protein and oil are used in the food industry (baking, confectionery, etc.), as well as for feed production. Oil is also a feedstock for the production of diesel fuel components. The implementation of these byproducts can improve profitability by 10-12%.

At the same time, the transition to the use of biofuels needs to upgrade petrol stations and sales network, as well as to give interest to domestic oil traders (who are the owners of these stations) to enter the market. Prospects of the development of the domestic bioethanol market in Ukraine are encouraging: after 5-8 years, when it will be fully in the process of production of alternative fuels, the country will have a significant niche in the fuel market.

The use of bioethanol as a gasoline additive will help to significantly reduce the deficit, but also improve the ecological state of Ukrainian cities and highways.

The production and use of biofuels in agriculture in our country is an objective prerequisite for the creation of additional jobs, increase of rural em-ployment, increase the production efficiency and well-being of people. After all, the vast majority of processing enterprises are located in rural areas, and for some settlements, they are the main taxpayers for the local budgets. Social and domestic infrastructure of rural settlements are built on their basis, and the spasmodic work of refineries pesters the most vulnerable segments of the population, leads, in particular, to the problems of heat and electricity providing to kindergartens, schools, residential homes.

The production of bioethanol will have an extremely positive effect on Ukraine, and create a number of socio-economic benefits. The introduction of modern innovative technologies in the area of energy will reduce the dependence of the economy on the countries-exporters of oil and gas, which, respectively, will increase its energy, economic and national security and will facilitate the exit of our country to a qualitatively new level of relations with foreign countries-exporters of oil and petroleum products, and position itself as a country with a European level of energy, economic and environmental security.

Basic definitions and concepts. *Bioethanol. Bioconversion. Ethanol. Methyl alcohol. Organic synthesis. High-octane additive. Enzymatic ethanol. Molasses. Sugar-containing feedstock. Diethyl ether. Ethanol. Decalitre. Alcohol hydrolysis. Ethylene. Hydrolysis. Alcohol sulfite. Condensation. Utilization. Factions. Ether. Azeotrop.*

Test questions and tasks

1. What is ethanol?
2. What can be used as a feedstock for ethanol production?
3. What types of materials should be used for the production of bioethanol in Ukraine?
4. What is the denaturation of bioethanol?
5. What can not be used as a denaturing agent?
6. Describe the condition of bioethanol in the world.
7. Give an analysis of certain aspects of ethanol production capacity in the US.
8. What are the features of the production and use of bioethanol in Brazil?
9. What are the features of the bioethanol plant in France.
10. List the main stages of bioethanol production.
11. What by-products can be obtained as a result of processing feedstock for bioethanol?
12. How can we use vinasse?
13. What culture provides a positive and which is negative energy balance in the production of ethanol?
14. What are the features of bioethanol?
15. Describe the potential of ethanol output of various crops.
16. What are the benefits of bioethanol production from sugar beet?
17. What are the main areas covering the concept of bioethanol in Ukraine?
18. Describe ways to use ethanol as a motor fuel.
19. What percentage of ethanol is used in gasoline-ethanol blends without changing engine design?
20. What are the promising areas of production and use of bioethanol in Ukraine?

CHAPTER 4
EFFICIENCY OF PRODUCTION AND USE OF BIODIESEL

Key issues

4.1. General Concepts, Aspects of Production and Use of Biodiesel
4.2. Feedstock for Biodiesel Production
4.3. Biodiesel Production Technologies
4.4. Glycerine Separation and Purification
4.5. Future Direction of Transesterification Technology Development
4.6. Standards for Biodiesel
4.7. Features of Using Biodiesel as Motor Fuel
4.8. Biodiesel from Algae as Third Generation Biofuel
4.9. Prospects for Biodiesel Production in Ukraine

4.1. General Concepts, Aspects of Production and Use of Biodiesel

According to the Law of Ukraine "On Alternative Fuel", **biodiesel** is methyl and/or ethyl esters of the higher organic acids derived from vegetable oils or animal fats used as biofuel or bio-components.

Vegetable and animal oils as fuel have been used since ancient times. In ancient times, olive oil was poured into lamps. Whale oil was used extensively for lighting in the 17th century. However, when it has become more expensive, people began to use kerosene.

The history of using vegetable oil as an alternative fuel dates back in 1990 from the World Exhibition in Paris, where Rudolf Diesel received the highest award for his first engine on pure peanut oil. However, at that time biofuels were much more expensive than traditional fuel oil, because its practical use has been suspended until the end of 20th century, when intensive development of effective technologies for producing biodiesel was renewed.

Commercial use of biodiesel began in the early 90-ies of 20th century, especially in those countries that rated real long-term benefits from its use and take appropriate decisions on national implementation.

The United States and Germany are among the largest biodiesel producers in the world, totaling some 4.7 and 3.4 billion liters, respectively, in 2014. The United States is projected to reach production levels of over 1 billion gallons of biodiesel by 2024. In 2010, the U.S. exported about 85 million gallons of their biodiesel products. Comparatively, Argentina accounted for over half of the world's total exports. The United States has one of the highest bioenergy capacities in the world, totaling 13,512 megawatts in 2014.

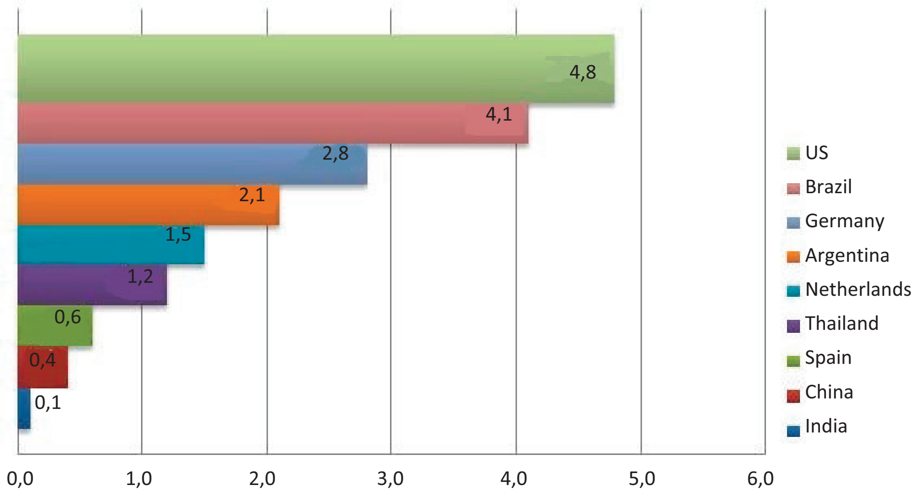


Figure 4.1. The World's Biggest Biodiesel Producers in 2015, by country (in billion liters)

The first attempt to get to market of biofuels was met with fierce opposition by automakers. They did not give the warranty for owners who poured the tank with biodiesel fuel instead of the traditional diesel origin. But with the encreasing of «black gold» price and concerning the environmental problems of humanity, owners of automobile giants have begun to pay more attention to the use of biofuels and stared to produce cars that can run on blends of diesel with biodiesel.

The use of biodiesel is beneficial both in economical and ecological point of view. It is made from raw materials that are renewed annually, non-toxic, readily biodegradable, reduces harmful car emissions significantly.

4.2. Feedstock for Biodiesel Production

The main raw material for biodiesel production is fat oil. Sometimes essential oils of various plants or algae are used. Also we can use vegetable oil, animal fat, fish oil and so on. The production of oil from different raw materials from 1 hectare is given in Table. 4.1.

Table 4.1

Average Yield of Vegetable Oil by Pressing

Culture	Yield, c/ha	Oil content, %	Output of oil from 1 ton of raw, litters	Output of oil from 1 ha, litters
Sunflower	25	52-57	400	1000
Soy	22	16-27	200	440
Rape	18	40-45	420	1190
Hemp	10	30-38	340	756
Peanut	16	41-50	470	752
Mustard seeds	15	32-44	400	600
Linen	12	40-48	440	528
Jatropha	35	27-40	340	11900
Palm oil	9	40-70	550	5000
Microalgae	190	50	500	95000

The selection of feedstock for biodiesel production depends on the geographic location of the country, the cost of feedstock, the output of oil from 1 ton of raw material and 1 hectare. So, the main feedstock for biodiesel production in the EU are rapeseed and soybeans, soy in the US, canola (a form of rape) in Canada, palm oil in Indonesia, palm and coconut oil in India, jatropha in the Philippines, soy and jatropha in Africa and castor oil in Brazil.

The cheapest feedstock for biodiesel production is palm oil. It has beenused for biodiesel production since 1987. However, due to high turbidity temperature (11°C), its use is limited to countries with tropical climates. In addition, hundreds of hectares of rainforest are cut down every year to plant palm plantations, threatening the ecological security.

In Ukraine, the most promising plants for biodiesel production are rapeseed, soybean and sunflower.

The production and use of biofuels in agriculture are paid much attention in the energy-dependent countries. It is believed that demand for oilseeds will grow faster than demand for the products of feed and food markets in the medium term in the EU. It will lead the agricultural sector to a new level of income (capital) flow. Until recently, agriculture could rely only on the funds spent by people for food. But those profits at reasonable prices and demand were not enough, so agricultural sector support required a great burden on the state budget. The ability to provide consumers with clean energy gives a new direction of agriculture development. The production of biodiesel allows using agricultural lands, which had not been used for long time, in order to create new jobs.

In some regions of Ukraine, the area seeded to oilseeds is expected to increase. Increasing of cultivation of oilseeds such as canola and soybeans will allow increasing the resources of high-protein feed for livestock and poultry with simultaneous organization of biodiesel production, especially for the needs of agricultural enterprises and for export.

Rapeseed is a universal culture, which occupies about 10% of the total acre-age of oilseeds in the world. Rapeseed ables to produce stable yields annually an average of 20-25 kg/ha (average yield of sunflower is 10-12 kg/ha). Improving soil structure and its phytosanitary status, enriching it with nitrogen and other microelements, rape is a fine precursor of grains (especially wheat), which significantly increases their productivity. Important elements of growing technology and the use of rape and other oilseeds on energy purposes is a process of gathering, processing, storing and recycling of by-products. In particular, rape straw can be used as biomass for burning and it is one of the best among crops. Its energy value increases significantly the overall efficiency of rape as a crop.

Rape seeds contain 38-50% of oil, 16-29% of protein, 6.7% of fat, 24-26% of nitrogen free extract. Rape is an extremely valuable fodder crop. 100 kg of seeds produce 41 kg of oil and 57 kg of oil cake. A hectare of this crop (yield 30 kg/ha) provides output about 1,0-1,3 tons of oil and 1,6-1,8 tons of meal that contains about 40% of well-balanced amino acid composition of protein. 100 kg of rapeseed meal contains 90 feeding units, digestibility coefficient of organic matter reaches 71%, and sunflower – 56%. During the processing of rape seed with low-waste technologies, there are a number of products in addition to oil and oil cake (meal). In particular, phosphates are selected during cleansing of oils, which are used in the production of food and feed phosphate concentrates. They are used in soap making, as well as to obtain fatty acids. Deodorization waste and worked sorbent are used for making the cleaning paste. Rape processing technology is shown in Fig. 4.2.

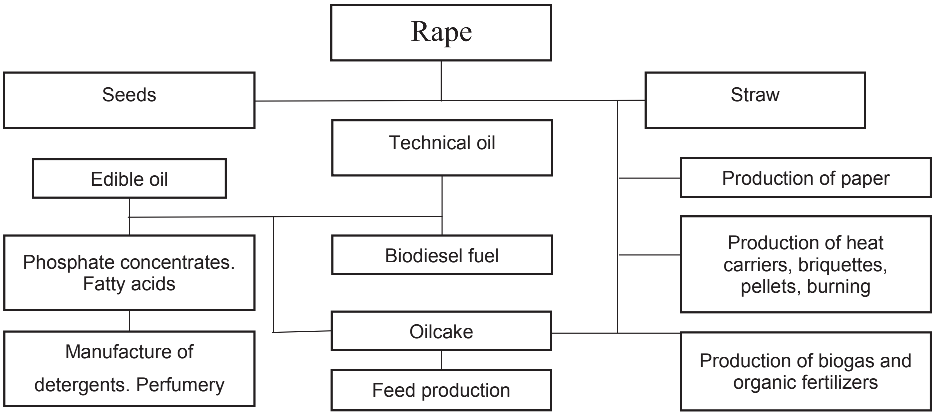


Figure 4.2. Scheme of Low-Waste Rapeseed Processing Technology

There is an ability to restore stocks of soil organic matter when we use rape as green manure. Plowing down green material in crop sowing (240-260 kg/ha) is equivalent to the inclusion of 18-20 tons of manure per hectare. After harvesting each hectare of soil, there is the amount of organic residues that is equivalent to 20 tons of manure.

In addition, scientific studies show that rape is an excellent precursor for all crops (except cabbage and sugar beets). Penetrating into the ground to 3 m, its rape root system forms an air passage and thus loosens the soil. Rape leaves residues roots in the soil 6-7 times more than wheat, and twice more than the clover. Soil with roots of winter rape remains 65 kg of nitrogen, 34 kg of phosphoric acid and 60 kg of potassium, which is almost 2 kg of ammonium nitrate, superphosphate 1.7 kg and 1.5 kg of potassium salt per 1 hectare. For example, the yield of winter wheat after rape increased by 6.7 kg/ha.

The perspective direction of development of raw materials for biodiesel in Ukraine is to increase the area of technical rapeseed and rapeseed oil production as a raw material to obtain biodiesel. In particular, the needs of agricultural production in diesel fuel can be fully provided if a rape crops will employ 8-10% of arable land with good yields and processing of rapeseed for biodiesel. The potential of known varieties of rape used by 50% or less. Therefore, an important task of executives is to reduce crop losses at all stages of the cycle of growing, harvesting and processing of rape.

From the combination of positive properties rape is a strategic crop. Using the genetic flexibility farners have the opportunity to withdraw varieties with desired properties. They have raised varieties with low content of erucic acid (2%), which is important for the production of biodiesel and glucosinolates (1%), the need for food purposes and the use of processed products for animal feed.The strategic importance of rape cultivation is the high energy value of crop seed and rape straw; the possibility of introducing low-waste, environmentally sound technologies (Fig. 4.3).

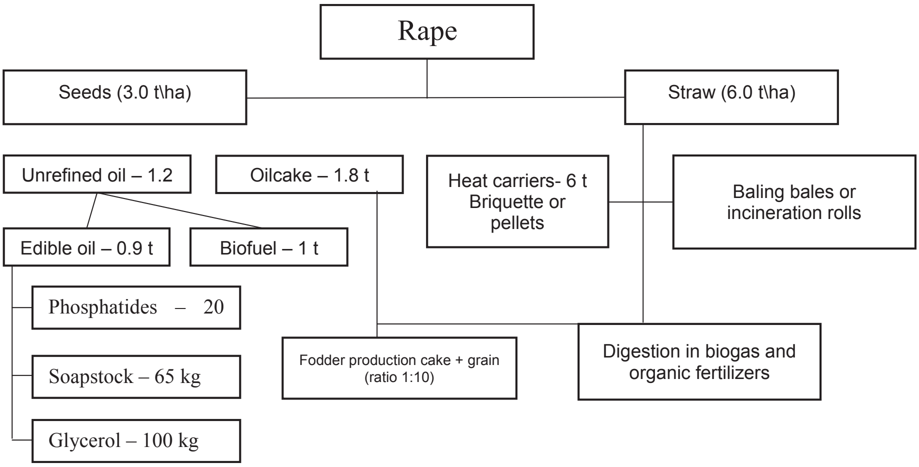


Figure 4.3. The Approximate Structure of Rapeseed Processing Products from an Area of 1 Hectare Using Low-Waste Technologies

In recent years, the link between domestic and world markets of oilseeds and products of their processing becomes more dense, due to the deepening of the process of the international division of labor and the entry of Ukraine into the world leadeship of the production of oilseeds, including sunflower, rapeseed and soybeans. The demand growth for the use of vegetable oils in biofuels industry will lead to a significant increase in gross yields of oilseeds in Ukraine. However, almost all rape and soybeans grown in Ukraine are exported abroad (Fig. 4.4). Enterprises remain only the part of the raw materials they need in the future for seeds. But Ukrainian rapeseed and soybean oil are not used for the confectionery industry abroad, but as oil for processing into biodiesel.

To increase the energy security, Ukraine's agriculture must be transformed from energy consumer to producer. An agricultural work on techno-logical standards requires around 1870 thousand tons of diesel fuel and 620 thousand tons of gasoline each year. To produce this amount of fuel, about 4.5 million tons of oil (mostly imported) are used. In this regard, the steady growth of its value leads to an increase in the cost of petroleum products and therefore agricultural products. So in 2000-2013, AIC costs

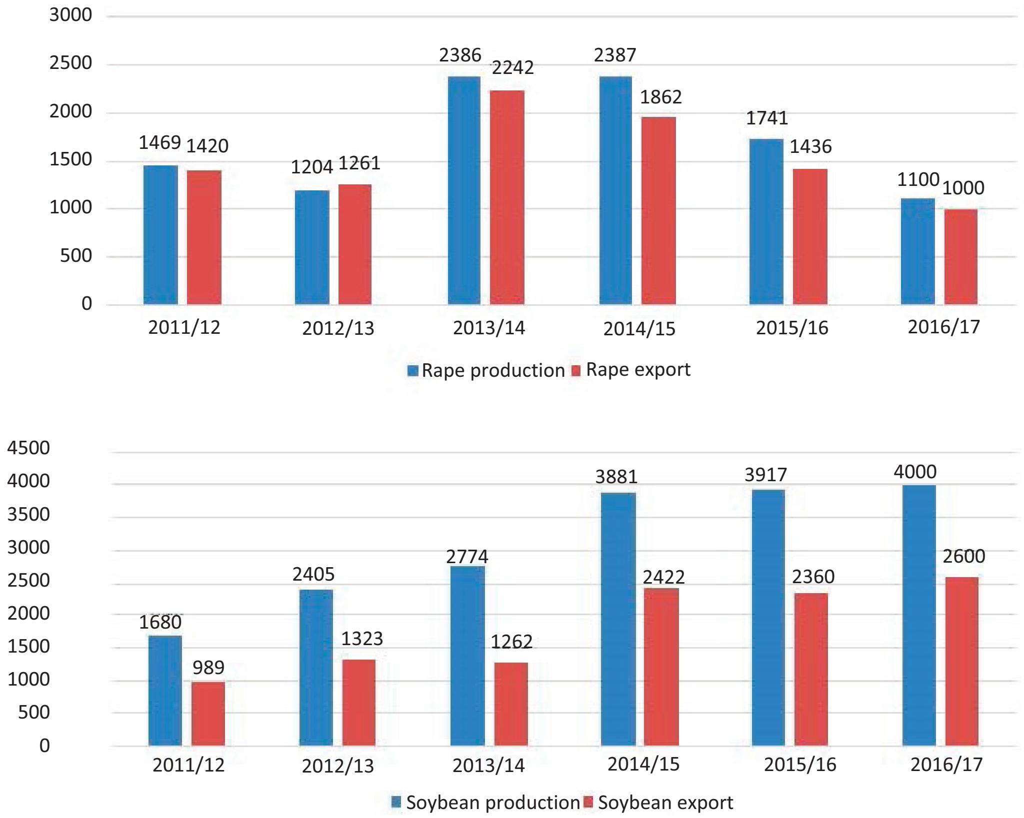


Figure 4.4. Production and Export of Rape and Soybeans, thousand tons

for the purchase of fuel increased by almost 6 times. Therefore, the traditional version to meet the needs of agricultural production due only to petroleum products is unpromising.

Exports of soybeans in 2016 were 2.46 million tonnes, rapeseed – about 2 million tons. Given that the oil content of soybean and rapeseed is 17-25% and 48-52%, respectively, Ukraine could produce about 900 thousand tons of vegetable oil, which would make it possible to cover 100% of the biodiesel needs for agribusiness.

Higher level meating needs in agricultural products in general, for food security and for biodiesel, requires a higher quality of food production with its improvement and better results.

The potential for other oil crops as feedstock for biodiesel prodution is not yet sufficiently investigated. The use of nut oil started in Nicaragua, experiments on the use of cotton oil is successfully carried out in Greece. In India, biofuels derived from nuts that grow on unsuitable for cultivation land. In areas with temperate climates, biodiesel can be obtained from sunflower oil, castor, hemp. In England, to obtain biodiesel they use vegetable oil, the amount of which reaches 70 million liters per year. Components of feedstock for the production of biodiesel can also include meat processing plants (animal fats), fish oil, algae and other materials.

The analysis of recent research and publications shows that the material basis of economic development is the amount of capital and technology are the basic elements of the productive forces. They make possible the development of production. Only a high level of its development with availability of required large number of high-quality production resources, including advanced technological capabilities, allows us to increase production of agricultural products.

The growth and reproduction of the means of production and its productive forces, above all, requires the strategy of intensive development of the most comprehensive use of resources required. This factors have become the basis for future development of the economy.

The AIC has to find an uncompromising position on the agreed reliability of food security with aspirations of plant material for biodiesel. Food security must be considered from the standpoint of guaranteeing the public free access to food at reasonable prices.

Today, significant changes are occurring in the production of oilseeds and their growth and reproduction. These complicated processes need system research. Today, many explanatory techniques, including the scientific community regarding the cultivation of oilseeds and as a food product and as a feedstock for biodiesel, which they have used for decades, were not justified. They almost did not contribute to the understanding of the processes occurring in the global economy.

For a comprehensive realistic assessment of the situation on the basis of the system without complications of methodology of energy resources, we have to analyze the current scientific works. There is a list of previously unsolved aspects of the problem:

1. The market development of oilseeds and their products in the whole world and in Ukraine are not considered in two interrelated dimensions: in the agriculture and manufacturing industries. Waste from the cultivation of oilseeds can be used as feedstock for biodiesel. However, this production is not oriented to international standards.

2. Do not set the main factors that contribute the intensive development of biodiesel market and especially the formation and functioning of oilseeds.

3. The issue to overcome the differences in the development of this market it has been worked. The aspect of simultaneous increase of biodiesel production and volume of food resources in the sector is not considered.

It is obvious that it is impossible to understand the essence of biodiesel from the view of former concepts of production in general. It is important to identify new trends and perspective directions of transformation of oilseeds production.

As for defining goals question, taking into account all the above, they should include the following tasks:

- compare the trends of development between gross output of oilseeds, level of productivity, absolute growth, including by productivity raising and the increase in gross harvest of oilseeds in general in the world and in Ukraine, and due to the results of such analisys to determine the most appropriate type of so-called «international standard»;

- clarify the nature of the main factors that contribute to the intensive development of biodiesel, and on this basis to reflect the perspective directions of improving growth and reproduction oilseeds market as a feedstock for biodiesel.

The formation of the biofuels market in Ukraine today is a difficult phase of development, so there is an urgent need to expand and deepen research on the development of innovation capacity building energy crops, the formation and functioning of their market as a feedstock for biofuel production. The current situation requires the development of biofuel development tools to research the demand and supply of energy crops, price dynamics, determination of market size, segmentation and of his prediction. This should take into account that the functioning of the market of biofuels remains the central tenet of economic theory – increase the efficiency of agricultural production. This is a prerequisite for increasing the competitiveness of domestic products in domestic and foreign markets.

Thus, there are favorable natural and economic conditions for the development of the energy crops as feedstock for biofuels production, labor and scientific potential, growing demand in the domestic and global markets, contributing to market development of energy crops, accelerated advancement and market development for biofuel production in Ukraine.

Mandatory biofuel content requirements are used in 62 countries. They stimulate the biodiesel market growth. In 2013, the world production of biodiesel increased by thirty times compared to 2000 and amounted to 27.5 billion liters. According to forecasts of FAO, its production in the world will continue to grow and will reach 42 billion liters by 2022. The largest producers are the EU,the USA, Brazil, Indonesia and Argentina – 3% (Fig. 4.5).

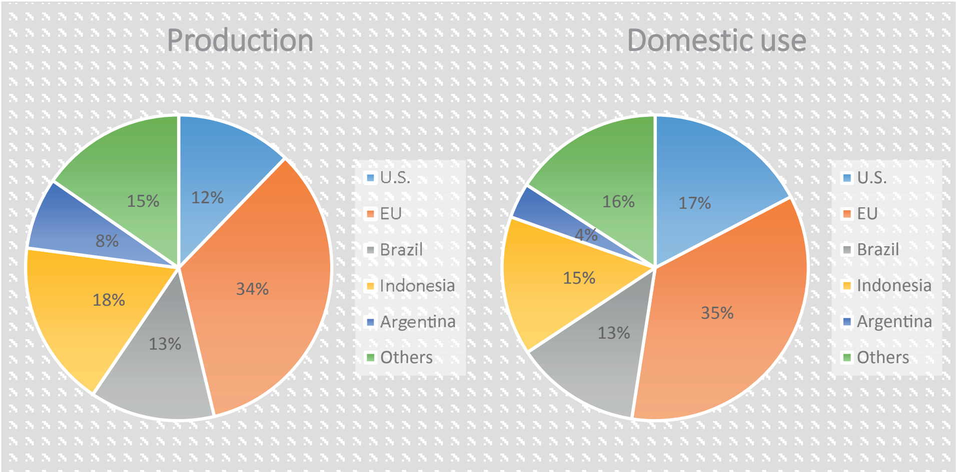


Figure 4.5. World Experience of Production and Consumption of Biodiesel

The EU's guidelines contain a plan concerning the increasing of future share of biofuels used by the European vehicles fleet. Biodiesel was the first type of liquid biofuel, which has been produced in the EU in the early 1990s. Now the share of biodiesel is 70% of the total consumption of alternative fuels in transport in Europe. The largest producers of biodiesel in the EU are Germany, France, Italy, Spain and the Netherlands (Table. 4.2).

The main reason why the European Union rapidly began to increase production and consumption of biodiesel was the increase of public concern on environmental issues (air pollution in large cities, global warming, the main cause of which scientists call intensive human use of fossil fuels). Over the last years another problems are added – the desire to ensure the energy independence of the Member States. This is the actual reason for Ukraine.

Today, a number of processes biodiesel from vegetable oils is developed. Based on the analysis, there are three operations of all known technologies of biodiesel production: preparing a mixture of catalysts; mixing vegetable oil with a mixture of catalysts; separation from vegetable oil obtained by a chemical reaction of glycerol. One of the most complex operation is the mixing of vegetable oil and catalysts. Liquid mixing in general was not investigated enough. Practical experiments remain the only source of reliable data.

Table 4.2

EU Biodiesel/HVO Production Main Producers (Million Liters)

Calendar Year	2010	2011	2012	2013	2014	2015[e]	2016[f]	2017[f]
Germany	3,181	3,408	3,106	3,307	3,808	3,351	3,350	3,410
France	2,295	2,090	2,516	2,476	2,681	2,442	2,215	2,390
Netherlands	434	558	1,337	1,562	1,954	1,988	1,990	1,990
Spain	1,041	787	545	668	1,016	1,103	1,070	1,080
Poland	432	414	673	736	786	795	800	800
Italy	908	704	326	521	658	665	665	665
Belgium	494	536	568	568	568	568	570	570
Portugal	328	419	356	307	325	440	443	455
Finland	375	253	320	399	409	409	440	440
United Kingdom	227	261	364	648	648	648	650	420
Others	992	1,611	971	791	488	1,126	1,487	1,935
Total	**10,707**	**11,041**	**11,082**	**11,983**	**13,341**	**13,535**	**13,680**	**14,155**

e = estimate/f = forecast EU FAS Posts. Source: FAS EU Posts based on information in MT and converted to liters using a conversion rate of 1 MT = 1,136 liters.

Systems of production and use of biodiesel from oil seeds in the member states of the European Union are different. The difference consists of the following:

- the degree of concentration of production;
- technology used to produce biofuels;
- percentage of biofuel in the mixture;
- organization of production, mixing and distribution.

In Europe, biodiesel is mainly used in two principal schemes, "French" and "German". The French scheme provides a centralized production of biofuels on powerful units. The main consumer of biofuels is transport, including buses, driving of which in some major cities and in some provinces on the traditional diesel fuel is prohibited. Thus the penalties for failure to comply with the emission of toxic substances exceed the difference in cost of biodiesel and diesel fuel. Based on this scheme, in France, biodiesel is produced mainly centrally on powerful units – 5-10 thsousand tons per year. The "German" option of obtaining biodiesel accomplishes in small decentralized units of transesterification, each of which can process rapeseed that are harvested from 5-10 thousand ha.

Rapeseed oil is the main feedstock for biodiesel production in the EU, its share is two-thirds of the total feedstock. The use of soy and palm oil for biodiesel pro-duction in the EU is limited to standard DIN EN 14214. At least 1.5 million tons of vegetable oil are used for biodiesel imports (palm, soybean, rapeseed oil less).

4.3. Biodiesel Production Technologies

The processes of extrusion and cleaning of vegetable oil are required steps for biodiesel production. At the same time, oil must meet high quality requirements for energy purposes.

Full technological processing of obtaining biodiesel from seed consists of three stages:

- receiving of feedstock, storage in vessel with the required spaciousness and supply to a section of the pressing;
- pressing of seeds to extrusion line, filtering (cleaning) and neutralization of oil, its storage and delivery to the section of esterification;
- production of biodiesel from oil in the esterification line, its storage and shipment.

At the first processing step, workers take raw seeds, store in vessel and feed to the pressing section. An important step in the production of biodiesel is the purchasing of seed (variants may be different) in order to provide functioning of plant during the year. Cleaned and dried rapeseed is stored in technological storage, which is located next to the oil mills.

Different varieties of seeds, intended for the production of oil, should have a moisture content of 5-7%, infestation – less than 1%, erucic acid content – less than 2% and an acid number – not more than 3. Violation of these requirements undermines the effectiveness of squeezing oil and its esterification, and can lead to lower quality of oil. This is caused, in particular, by the degree of ripeness and seed storage conditions.

At the second stage of processing, the seeds are taken from the vessel and feed to the prior prepearing equipment, where they are released from irrelevant items, impurities, dust, etc. Then the seeds are dosedly served in a screw press where the process of squeezing oil is going on. Oil from rapeseed is pressesed by squeezers with productivity from 200 kg/h to 100 t/h, depending on the scale of production.

Screw, single or multisection presses are fommonly used. They be equipped with previous chambers, where the seed is heated, which improves the process of squeezing oil. Approximately 40-44% of rapeseed in dry weight is fat, and after a single squeezing there is 10-12% of fat in the pulp.

In the process of cold squeezing, the oil temperature does not exceed 50-60°C. Special presses are applied for this squeezing. They are a part of the pro-duction lines for vegetable oil. The obtained oil flows into the vessel, and then is served in the filtration installation, where the separation of solid particles is taking place.

Then oil is a subject to further purification by precipitation of phosphate compounds and free oil acids are neutralized and washed. Then the oil is dehydrated and stored in a vessel of clean oil.

Sometimes the double squeezing is used. In this case the oil content in meal is reduced to 6-8%, but the process requires additional costs, energy particularly, as the second squeezing is held at high temperature using heated materials. Warming of seed and oil cake has negative effect on the quality of the feedstock for biodiesel, if it is produced on commercial or small-capacity plants.

After the first squeezing with pre-heated and crushed seeds, oil industry enterprises mix the pressed skins with solvents in extraction chamber (benzene, hexane), where remaining fat portion is dissolved. This mixture is heated, and the solvent vapor is condensed and recycled.

There is only 1-2% of fat in the process of meal extracting. Obtained during the extraction oil is mixed with oil after the first squeezing in a ratio of 2:1. The extraction oil is usually dirty, because solvents extract the oil with a large number of toxic substances. The use of solvents causes emissions to the environment in quantities of 2-4 kg per 1 ton of rapeseed, which is in several times higher than European standards, which were introduced in 2007.

In contrast to extraction, cold squeezing of oil is completely neutral method for environment and cold meal after squeezing is a valuable food for all kinds of animals (with appropriate proportions in feed mixtures). Meal that formed by pressing seeds contain fat (8.12%) and protein (30-32%). They are fallen from the screw press and have a form of plates, transported to a bruising mill for crushing into small particles of a same size. In this form, it is submitted to the mixer, which also has all wastes from the process of oil filtering and refin-ing. Mixed husks that have a high temperature, are sent to the cooler. Then they are transported in storage and kept until sending to the consumer or to the feed mills for further processing.

Rape cake or meal can be used for:

– further processing to feed;
– subsequent transformation from biofuels (pellets or biogas);
– settling with farmers;
– selling on the agricultural market.

Considering the fat content, meal storage period should not exceed 3 months. The share of meal in mixtures of specific groups of animals is different. It can be used in the feed mix for meat cattle (the share is 40%), for dairy cows (30%) and poultry (only 5%). A small proportion of meal in poultry forage mixture can be explained with the high content of fiber in the meal, which is a limiting factor. Attempts to apply the methods of breeding and genetics to reduce the fat content by increasing the seed weight and change a structure of seed capsule and mechanical degreasing of rape seed did not give technical results that could reduce fiber content. In addition, the meal is a valuable feed for fish and fur animals. Numerous studies of feeding milk cattle and meat cattle showed that meal have a positive affect on the final product without reducing its quality.

In the balance of economic calculations of biodiesel production (rapeseed-oil-methyl-ester, RME), in addition to the price, funds from the sale of meal (about 2/3 of rape seed mass) play a very important role. The additional incentive for the processing of rape to esters is the possibility of obtaining glycerin, which is in demand and not harmful to the environment.

Important elements of biodiesel production (RME) in the second stage of processing of raw materials is a process of filtration and neutralization of oil. Neutralization, bleaching and deodorization are sufficient for oil production for food purposes. The production of biodiesel requires only filtering and neutralization of oil (before its esterification).

The process of neutralization with alkaline can adversely affect on the environment, and there is necessity of appropriate technological support.

Traditional power systems of diesel engines may not work in oils without changing their designs. Therefore, since the 80's of 20th century, it the possibility of production of motor fuel from vegetable oil that can be used directly or as an additive to conventional fuels has been extensively studied.

The result of the research was the technology of biodiesel obtaining during its synthesis from vegetable oils and methanol.

RME or Rapeseed-oil-methyl-ester was the first type of Biodiesel fuel produced commercially in 1988, characterised as a single-feed-stock product of the questionable quality. Depending on the applied technology and products, biodiesel has many names: biodiesel, RME, FAME (*Fatty Acid Methyl Esters*), bio oil, biofuel, ekol etc. From a chemical point of view, it is a mixture of different *fatty acid methyl esters*.

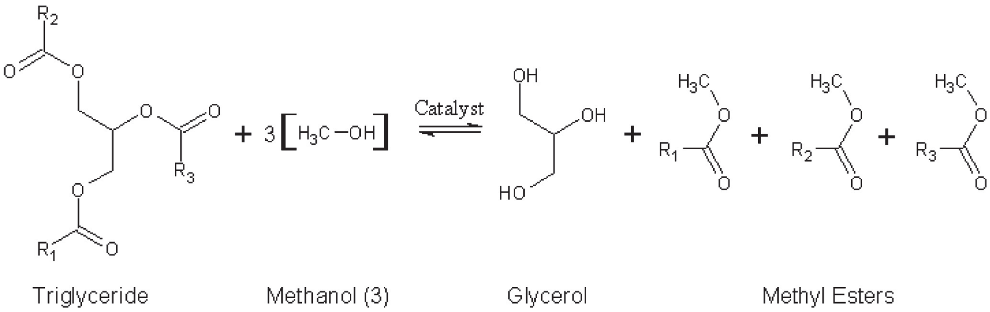
Esters of vegetable oils can be used as a fuel in a pure form or as a blend with conventional diesel fuel for diesel engines or as fuel for heating systems. In the EU, esterification of vegetable oils is implemented industrially and sanctioned by law and regulations. Almost every type of vegetable oil and unused animal fats (even the waste after consumption) can be used in the production of esters.

The quality of rapeseed oil affects on the way of the esterification processes and the quality of esters. Increased acidity of the oil and the presence of water increases the catalyst costs and the number of unwanted by-products (soap). Incorrect oil filterring can cause difficulties in the final phase of esterification and reduce the quality of glycerol fraction. Increased volume of phosphorus (phospholipids) could cause a need for additional manufacturing operations in oder to meet requirements of quality standards.

RME is obtained as a result of esterification. Depending on the method of esterification, a mixture of methyl esters of fatty acids and glycerol fractions with different content of glycerol are received. The technology of biodiesel production from rapeseed oil is based on physical and chemical processing of filtered oil to methyl ester.

Vegetable oil is reesterificated with methanol, rarely with ethanol or isopropanol (approximately in the ratio of 1 ton of oil + 200 kg of methanol potassium hydroxide or sodium) at 60°C and atmospheric pressure.

From a chemical point of view, biodiesel is a mixture of methyl (ethyl) esters of saturated and unsaturated fatty acids. In the process of (re) esterification, oils react with methyl (ethyl) alcohol with a catalyst (usually alkaline – NaOH, $NaOCH_3$ or KOH). As a result, there esters and glycerin phase (56% of glycerol, 4% of methanol, 13% of fatty acids, 8% of water, 9% of inorganic salts, 10% of esters) are formed by the equation:



The basic technologies in the production of biodiesel are:
- cyclical using catalysts (Fig. 4.6);
- non-catalyst cyclical (using solvents, typically tetrahydrofuran);
- continuous with a lot of reactions.

In reactions with an acid catalyst, there is a necessity of high pressures and temperatures. When using basic esterification catalyst (NaOH), it is necessary heating up the oil to a temperature 60°C, but esterification process using potassium hydroxide KOH can take place at room temperature, but much slower.

Oil is esterificated with methanol into methyl esters with the release of glycerol under the influence of a catalyst. Removal glycerin with methyl esters is immiscible practically. So, after the reaction, there is mixture gravitational separation into two layers.

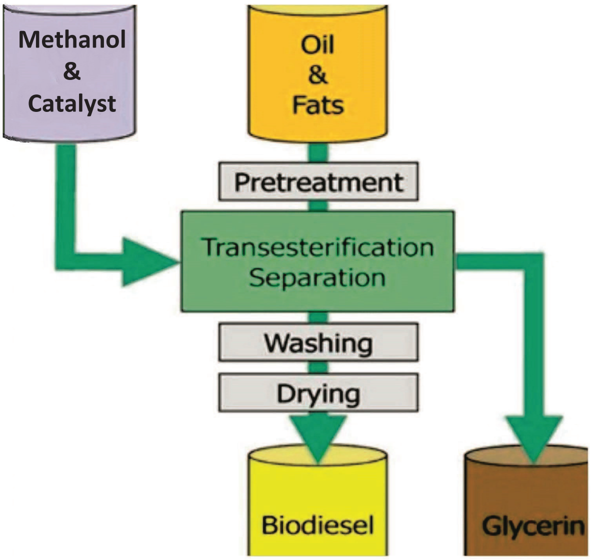


Figure 4.6. Cyclic Technology With Catalyst

After esterification process in a reactor, which lasts about 2 hours under atmospheric pressure at a temperature of 20-40°C, there is a separation of the mixture into two fractions: the dark, glycerin with a weigh of 1.25 kg/dm³ and a lighter, essential with a weigh of 0,85-0,88 kg/m³.

Essential fraction may contain incomplete esterification products (soaps, fatty acids and other components).

The degree of esterification and the composition and amount of pollution depend on the oil and applied clean technologies. These pollutions are removed by leaching and filtering, usually by centrifugal or thermal method, and excess of methanol – by distillation and returning it for further use.

Content of excessive amounts of water in the air of the final product requires the use of additional operations that make it possible to bring its share to the recommended limits.

Glyserol faction concerning its content of methanol and a large number of harmful substances should not be discharged into drains. After pretreatment in separators or by other methods we obtain the unprocessed glycerol which contain 50-60% of glycerol, which can be used as a 5-percent feed additive for pigs and poultry.

Crude glycerin, treated appropriately at specialized enterprises, is a valuable product suitable for food, pharmaceutical, cosmetic and other uses. Glycerol fraction with methanol containing is not recommended as a part of fertilizer due to air pollution.

The process of biodiesel production with "cold" technology is advisable to implement at small processing plants. An important factor in the application of this technology is the ability to reduce the volume and cost of transportation of raw materials and products for meal and biodiesel can be sent directly to agricultural producers. This model provides to obtain 691 liters of biodiesel (per 1 ha) and 1,300 kg of meal if rapeseed yields is 21 kg/ha.

In "hot" biodiesel production technology, the efficiency of transesterification process ranges from 90 to 99%. Glycerol phase is fed into the reservoir, and methyl ester is pumped into another reactor where the esterification process is repeated again. Glycerol phase is separated from esters in the separator. You can reach the 98 % purity level of esters. In this technology, mud consists of potassium soap, methanol, water and glycerol. The soap is washed away with acidified water.

Water and soap are pumped into the tank for process water and methyl ester – in the separator, which removes water, soap and glycerin. With methyl ester separator is pumped through a plate heat exchanger in the column where dry air removes remaining water and methanol.

Dehydrated and pure methyl ester is pumped into container for storage. The process can have periodic or continuous character. Process control for setting the dosage should provide oil solution of methanol and acidified wa-ter by flow meters. Technological water that includes potassium soap and not proreahovani substance before being discharged into the sewer network is purified in the cleaner effluent. Regardless of scale there is an essential value of the individual consumption of materials and raw materials to produce 1 dm^3 of biofuels. By-products are generated in the production process (meal contain-ing 10-12% oil and hlitserolova phase, which has a 40-45% pure glycerol) are valuable semi-finished products for further processing. Methanol is used in excess in the essential reforms of biofuels and distilled glycerol outflows, dehydrated and reused in the process. Glycerol opportunities depend on the scale. The glycerol fraction at the large scale production can be processed at the same factory for the industrial or pharmaceutical glycerine. The amount of glycerol fraction reaches 12% of the crude oil.

Advantages and disadvantages of basic technologies for obtaining biodiesel fuel are shown in table 4.3.

Table 4.3

Basic Technologies for Obtaining Biodiesel Fuel

Name of technology	Characteristic	Advantages	Disadvantages
Cyclic with the use of catalysts	Reaction temperature about 65°C, atmospheric pressure, reaction time from 20 min. up to 2 hours, the amount of catalyst is 1.5% by weight of the oil, the ether yield is about 85% of the total weight of biodiesel	Relative simplicity of the technological process; low cost of the technological line the possibility of using raw materials with low quality	Low ether output; long time reaction
The catalytic cyclic technology	Reaction temperature is 30°C, atmospheric pressure, reaction time 5 ... 10 min., solvent – tetrahydrofuran, ether yield – about 98% of the total volume of biodiesel	High ether yield; low temperature; high reaction rate	Need for expensive and aggressive solvents; need for additional equipment
Continuous	Reaction temperature 80...160°, pressure 2 ... 3 atm, duration reactions – from 6 ... 10 minutes, the amount of catalyst – up to 1% of the mass oils, the ether yield – up to 98% of the total mass of biodiesel	High output of ether; reaction rate high; continuity of the process	Complexity of the technological process; high cost oftechnological line; sensitivity to raw material quality

The choice of technology depends on the required production volumes, type of feedstock and their quality, methods of purification from alcohols and catalyst. By volume of biodiesel fuel production from 500 to 5000 tons/year, including the factories working with raw materials of low quality, it is better to have a simple cyclic technology using catalysts. For large volumes of production (more than 5 thousand tons of biodiesel per year), it is necessary to choose the continuous technology, that put strict requirements as for the quality of the original feedstock.

To produce 1000 kg (1136 liters) of biodiesel it is necessary to spend 50 kW of heat and 25 kW of electricity. The expenses of raw components are 1040 kg (1143 l) of rapeseed oil; 144 kg (114 l) 99.8% methanol (should be present in excess) 19 kg 88% potassium hydroxide (KOH) 6 kg of auxiliary filtering material; 105 kg of water.

4.4. Glycerine Separation and Purification

Glycerin as a formed by-product should be removed from the mixture of esters in the transesterification process, as it impairs the work of the engine, and fuel supply system. In addition, glycerol forms acrolein during the combustion in the engine cylinders. Acrolein is a carcinogen and degrades the environment. According to the requirements of the American Standard ASTMD 6751, glyc- erine content in the diesel fuel is limited to 0.4% wt., and the FRG DINV 1606 stan-dard and the European standard EN 142/4 determines 0,23% content of weight.

Methyl esters and glycerol are practically insoluble in each other and differ significantly in density. Esters density is 0.88 g/cm^3, glycerol – 1.05 g/cm^3. The presence of methanol, water and catalyst has little effect on the difference in density, which enables to use gravity technology for efficient separation of the phases.

The use of gravitational technology needs to consider that during the implementation of transesterification reaction in conditions of intensive locomotion, glycerol has a finely dispersed state in the mass of reaction medium. Therefore phase separation is necessary to create conditions for the separation of a the mix ture by gradually reducing the frequency of rotation of the mixing device.

THe most common equipment for the separation of the reaction mixture is a two-phase gravity separator. They use a large volume capacity and a high ratio of length/height with diameter of 5 to 10 or more. In cotinuously operating separators in order to provide the necessary duration of stay mixtures (1-8 h). In particular, continuous installation, which produces 16.5 ths. tons of biodiesel fuel per year, needs the separator capacity with 2650 m^3 to provide 1 hour lasting separation.

For the separation of esters and glycerol we can use a centrifuge that creates artificial intense gravitational field under the influence of centrifugal forces. They provide a quick and efficient separation of mixtures by major turnovers (2000-5000 rev/min) of rotor.

In recent years, for the separation of biodiesel fuel from glycerin, there are hydrocyclones with conical shells, inside of which there is a mixture spinning and stratification, the more difficult part (glycerol) is pressed to the outer wall of the housing and flows down and the light part (esters) is displaced to the center and to the top. THe mixture is fed into hydrocyclone tangentially under pres-sure 3,5-10 kg/cm^2 abs.

The obtained glycerol contains the residues of methanol, catalyst particles of raw materials and product esters and other organic remains of plant material, phosphatides, proteins, aldehydes, ketones, and other minerals.

In large power plants, methanol from glycerol phase is removed by vacuum distillation, in low power plants – by ion-exchange technology.

The alkaline catalyst in glycerol is neutralized with acid to the form salts. Soap is removed with coagulation and precipitation using aluminum sulfate or ferric chloride. The glycerine bleaching is carried out using adsorbent – activated carbon or clay of different origin. The water is removed by evaporation. All physical processes of glycerine purification is carried out at high temperatures (65- 90°C) to reduce viscosity.

The total output of glycerin in the transesterification is 10% by weight of esters.

Glycerin is an extremely useful product which can be used in many industries.

1. Agriculture. Glycerin is used for treatment of seeds and seedlings. Diluted solutions of glycerin help germination of oats and other cereals. With a view to processing plants and fruit trees it is used a mixture: the two parts of glycerol, one part of formaldehyde and 17 parts water.

2. Paint industry. Glycerin is a valuable component of polishing agents, lacquers especially, which are used for finishing treatment. In addition, a large number of varieties of toilet soap contains glycerin, which increases their washing capacity.

3. Production of plastic. Glycerin is a valuable part of receipt of plastics and resins. Glycerol esters are widely used in the production of transparent packaging materials.

4. The textile and paper industries. Glycerin is used in the textile industry in spinning, weaving and dyeing. Glycerin provides tissue elasticity and softness. It is used to produce aniline dyes, solvents for paints and as an antiseptic and absorbent additives for printing inks. Glycerin is widely used to produce synthetic silk and wool. In the paper industry, glycerin is used for the manufacture of tracing paper, parchment, papyrus paper and paper napkins.

5. Food industry. Glycerin is used for making extracts of tea, coffee, ginger and other vegetable substances; soft drinks. Each year Large companies are using more than 450 tons of top grade glycerin for preparation of the extract, which makes drinks softer. Glycerin is used to produce mustard, jelly and vinegar.

6. Medicine. It is used for manufacture of pharmaceuticals, in particular for dissolving drugs and increasing the viscosity of liquid products. Glycerin is a solvent io-dine, bromine, mercuric chloride and phenol. When using glycerin instead of water, it is possible to prepare highly concentrated medical solution. Antiseptic and preservative properties of glycerol linked to its hygroscopic by which bac-terias are dehydrated.

7. Electricity and radio. In radio engineering, glycerin is widely used in the manufacture of electrolytic capacitors; the processing of aluminum and its alloys.

8. Military affairs. Glycerin is used to produce nitroglycerin, which produces dynamite, smokeless gunpowder and other explosive substance, which is used for peaceful purposes.

9. The tobacco industry. Due to the high hygroscopicity glycerin is used to regulate tobacco humidity to eliminate the unpleasant taste. The worldwide production of tobacco use more than 12 thousand tons of 94% aqueous glycerol every year.

Another byproduct is formed in the process of squeezing oil for cold technology is lecithin, which belongs to the phospholipids. The number of produced lecithin consists of approximately 5% of the feedstock formed from crude oil. This product can be used in food, chemical and pharmaceutical industries.

Rape diesel biofuel is mixed in the indicated proportions with the traditional standards of diesel fuel, with the addition of certain additives to stabilize its quality. By assessment of the basic properties of biodiesel (RME) giving its fire safety, it has been found that a mixture of vapors with air biofuel does not form explosive mixtures. It is important to mention that diesel fuel vapor form an explosive mixture with air unlike the RME, which has a low explosiveness limit.

4.5. Future Direction of Transesterification Technology Development

The development of existing technologies of biodiesel by transesterification of triglycerides occurs in the following areas: increasing the degree of conversion; effective separation of the reaction products; effective removal of used catalyst; efficient extraction and purification of glycerol; reduce the formation of saponification products; reducing the reaction time; continuous development of new technologies and methods of continuous withdrawal of concomitant glycerol from the reaction zone; development of new methods to increase the contact surface phase of reagents and others.

Among essentially new areas of technology transesterification of triglycerides, we should note enzymatic catalysis of reactions, which are carried out by lipases at relatively low temperatures (35-45°C), immobilized on barrier of reactor or suspended in a mixture of methanol and triglycerides, followed by removal of the reaction mixture and reuse. These works are made in Japan and are still far from a commercial implementation.

Kyoto University (Japan) conducts the research on the non-catalytic transesterification technology, which is based on the properties of fluid at pressures and temperatures above critical, combine characteristics of both liquids and gases. Under these conditions, solvents having hydroxyl groups OH (such as water or low molecular weight alcohols), acquire properties super-acids that allow to use methanol for transesterification without an alkaline catalyst.

Researches concern the active strongly acid transesterification catalysts that could carry out the reaction without alkali and water in technological schemes. The company Benefuel (USA) informed on creation of such a catalyst that is based on a complex compound of duemetalic cyanide (iron and zinc). And it declared it jointly with the National Chemical Laboratory of India. The first implementation of this technology is expected to firm Seymone Biofuels, Illinois (USA).

Second-generation biodiesel fuel developed by a number of companies. The technology of the provides processing of vegetable oils using traditional refining technologies – hydrocracking and hydrofining. Biodiesel produced by such technol-ogy, called Green diesel (green fuel). The principal difference of the new fuel mixture of methyl esters of fatty acids is that it is no different from traditional pe-troleum fuels and can be used in all diesel engines without modification of either.

The output of green diesel fuel in installations hydrogenated vegetable oil is 98% or more, the output of byproduct of oil – at least 1%. The cetane number of diesel fuel is quite high – in the range of 80-100 units. The sulfur content is less than 10 ppm wt %. The green diesel is usually referred to as the second-generation biodiesel due to significantly better performance indicators (tabl. 4.4).

Table 4.4

Performance Indicators of Biodiesel of the Second Generation

Indicator	Unit	Methyl esters	Second generation biodiesel
Oxygen content	%	11	0
density	g/cm3	0.883	0.78
Calorific value	MJ/kg	38	44
Cloud point	°C	-5	(-5)-(-30)
Cetane number	-	50	80-100

The heat creating capacity of methyl esters is less because of the oxygen in their composition. In the production of green diesel, it is occurring the glycerol ele-ment splitting formed by a small amount of light carbohydrates (propane or lighter homologues), and there are no attendant glycerin. In addition, there are the reduced requirements as raw as hydrogenation processes almost do not react to the content of free fatty acids.

4.6. Standards for Biodiesel

Properties of biofuels are not sufficiently understood yet, because most of the existing standards are currently limited by indication of limit rate of esterification, temperature of blur and turbidity point, the number of total and free glycerin and others. Specified characteristics are a compromise between the demands of car manufacturers, who are supporters of clean fuel (without any additives), and biodiesel producers' desire to implement simple, inexpensive and environmentally friendly technology. Obviously, the more stringent standards for biodiesel will increase its value, while more loyal can lead to the removal of various shortcomings in the operation of vehicles. These two possibilities will certainly affect on further market development and perception of biodiesel.

In the world, the most popular standard for biodiesel is the European standard – EN 14214: 2003 (tab. 4.5).

Table 4.5

En 14214:2003 (E) Automotive Fuels – Fatty Acid Methyl Esters (Fame) for Diesel Engines – Requirements and Test Methods

PROPERTY	UNIT	MINIMUM	MAXIMUM	TEST METHOD
ESTER CONTENT	% (M/M)	96.5		PREN 14103
DENSITY 15°C	KG/M3	860	900	EN ISO 3675 EN ISO 12185
VISCOSITY 40°C	MM2	3.5	5.0	EN ISO 310
FLASH POINT	°C	ABOVE 101		ISO/CD 3679
SULFUR CONTENT	MG/KG		10	
CARBON RESIDUE (10% BOTTOMS)	% (M/M)		0.3	EN ISO 10370
CETANE NUMBER		51.0		EN ISO 5165
SULPHATED ASH CONTENT	% (M/M)		0.02	ISO 3987
WATER CONTENT	MG/KG		500	EN ISO 12937
TOTAL CONTAMINATION	MG/KG		24	EN 12662
COPPER STRIP CORROSION (3HR 50°C)	RATING	CLASS 1	CLASS 1	EN ISO 2160
THERMAL STABILITY				
OXIDATION STABILITY, 110°C	HOURS	6		PR EN 14112
ACID VALUE	MG KOH/G		0.5	PR EN 14104
IODINE VALUE			120	PR EN 14111
LINOLENIC ACID METHYL ESTER	% (M/M)		12	PR EN 14103
POLYUNSATURATED(>= 4 DOUBLE BONDS) METHYL ESTERS	% (M/M)		1	
METHANOL CONTENT	% (M/M)		0.2	PR EN 14110
MONOGLYCERIDE CONTENT	% (M/M)		0.8	PR EN 14105
DIGLYCERIDE CONTENT	% (M/M)		0.2	PR EN 14105
TRIGLYCERIDE CONTENT	% (M/M)		0.2	PR EN 14105
FREE GYLCEROL	% (M/M)		0.02	PR EN 14105 PR EN 14106
TOTAL GYLCEROL	% (M/M)		0.25	PR EN 14105
ALKALINE METALS (NA + K)	MG/KG		5	PR EN 14108 PR EN 14109
PHOSPHORUS CONTENT	MG/KG		10	PR EN 14107

State Enterprise "*Research Institute* of *Oil Refining* and *Petrochemical Industry*" *MASMA after carrying out* the analysis of international standards and recommendations for biodiesel, developed almost only valid normative document in the given field in Ukraine – SOU 24.14- 37-561: 2007 "Methyl esters of fatty acids for diesel engines". It leads to the conclusion that the basis for the development of national standards, which define technical specifications for biodiesel, could become the European standard *EN 14214:2003* (E) *AUTOMOTIVE FUELS* – FATTY ACID METHYL ESTERS (FAME) FOR DIESEL. ENGINES – REQUIREMENTS AND TEST METHODS. At the stage of production development of a new product in Ukraine, this standard may be changed according to real possibilities of domestic producers:

- to increase the maximum allowable water content in the product from 0.05 to 0.15%. When using the existing system of transport and storage of biofuels in the water, it collects three times more than it has been set by standard. So users must either increase the maximum permitted limit or to transport and store biodiesel in special watertight containers, which are separated from those that are used for diesel;
- to increase the maximum allowable free glycerol content from 0.02 to 0.05%. The requirement of the standard is set according to the ability of glycerol to release bound water. If the maximum allowable water content in fuel will be increased, there will be possibility to increase the content of free glycerol;
- setting the standards for the minimum content of an antibiotic that is used to prevent microbial growth in biodiesel, that is not used immediately after manufacture;
- reducing the minimum flashpoint temperature to 55°C. Most national standards set this figure at 120°C, although for fuel oil, it equals to 55°C. Installing a single indicator will not affect on cetane and lubricity ability and at the same time will increase the maximum concentration of alcohol from 0.2 to 0.5%;
- limiting the value of bound glycerol 0.08%, thus avoiding crystallization of monoglycerides;
- restrictions on free fatty acids, soaps and residual catalyst that existing standards are not available. This is true if alkaline catalyst and flushing the fuel after reaction are used. Limiting the number of ash in standards provides low content of these components. However, in the future, acid catalysts may be used. They are used in the operations of proven oil, or an alternative to water washing will be found. Regard this, the issue on introduction of the relevant rules will become more actual;

• introducing of the maximum allowable peroxide number (maximum degree of oxidation of the fuel is used in diesel engines). To develop standards for this indicator, there is a need for further research and testing.

All entities that develop or master the mass production of biofuels or plan to produce it under license, should be guided by the following regulations:

• GOST 15.001-88 System of design and supply of production. Products for industrial purposes;

• GOST 2960-94 Industrial production. Basic concepts. Terms and definitions;

• GOST 3021-95 Testing and quality control. Terms and definitions;

• GOST 3278-95 system design and supply of products for manufacture. The main provisions of the definition;

• ISO 4311: 2004 system development and supply of products for manufacture. Petroleum products and petrochemicals. Substantive provisions.

The influence of impurities on the quality biodiesel is shown in Table. 4.6.

Table 4.6

The Influence of Impurities on the Quality of Biodiesel

Impurity	Critical contents	Problems caused by the presence of impurities	Reduction exposure
Water	More than 0.15%	Corrosion of the fuel system and fuel tanks; development of microorganisms that clog filters and cause corrosion	Double cleaning, evacuation, addition antibiotic
Free glycerin	More than 0.05%	Formation sediments, releasing bound water and glycerol from the fuel	Washing
Bound glycerin	More than 0.3%	The formation of carbon particles on fuel injectors and piston rings, crystallization	Compliance technology
Alcohol	Over 5%	Reducing the cetane number and flash point, reducing the lubricating ability of the fuel.	Washing with subsequent evacuation
Fatty acid soaps	More than 0.02%	Ash formation	
Peroxides hydrogen	More than 70 units	Oxidation of biofuels, the destruction of rubber gaskets, adhesives and formation of insoluble precipitates	

Capital investments in the construction of biodiesel plant usually are below those needed for the construction of bioethanol, and largely depends on the type of feedstock planned for the processing. There are a number of published in the literature studies on volume of capital investments of various plants (eg Shumaker, Agri-Industry Modeling & Analysis Group Independent Biodiesel Feasibility Group, BIOX, Lurgii et al.). One of estimates of capital expenditure in the construction of plant for pre-treatment of oilseeds shown in Fig. 4.8 and 4.9. Accuracy evaluation is ± 25%.

As you can see on the Fig. 4.7, if the plant capacity is less than 15 million liters of biodiesel per year, relative costs are increasingthat is whye it is economically more feasible to build more powerful plants.

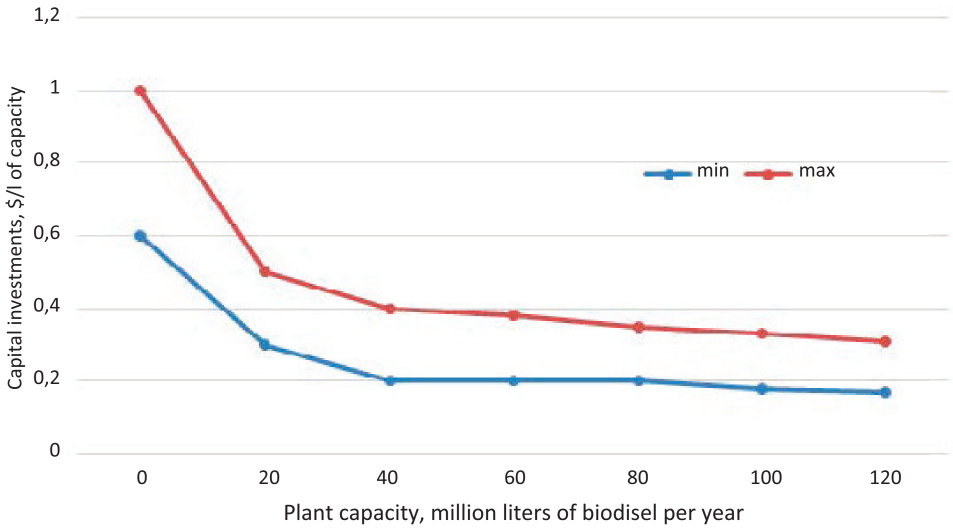


Figure 4.7. Dependence of Capital Costs on the Construction of the Plant on the Capacity of Biodiesel Production

Graphic images on Fig. 4.8 indicates that the construction of the plant with capacity of 1.9 million tons of biodiesel per year require more than a third of capital costs for equipment, 0.4 million of capital expenditures are spent on equipment.

Thus, regardless of the volume of investments, the only way to get profitable biodiesel plant is to carry out a thorough and detailed planning before construction.

It should be considered the following:

- to investigate thoroughly the market conditions for all products (not just the main reaction products, but also fatty acids and other byproducts). Such information could significantly impact the economy of the plant;

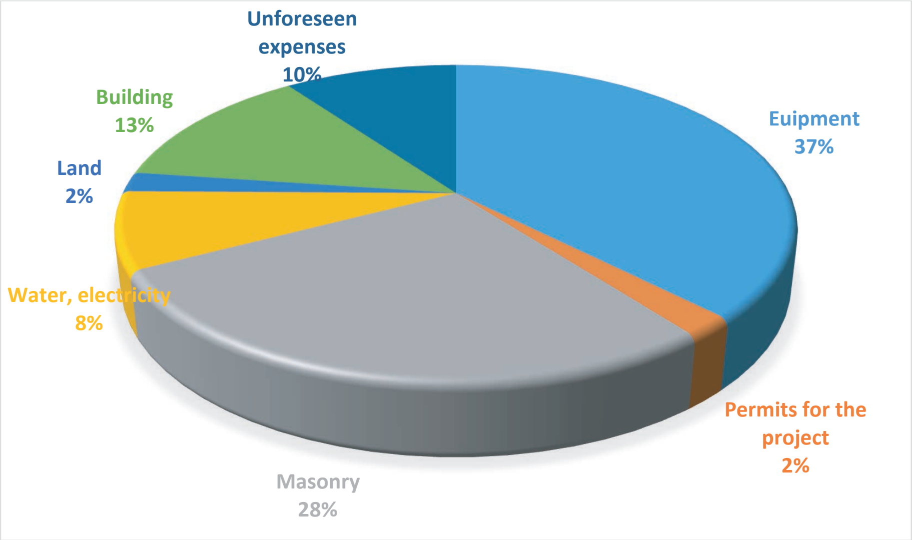


Figure 4.8. Structure of Costs for the Construction of a Biofuel Plant

• to make the market development model, focusing not only on the optimistic trend towards increased demand for biofuels, but also, for example, the possibility of decline in prices for glycerin;

• to consider the integration of the plant into existing industrial complexes. In particular, for companies that are seriously interested in producing biofuels, it makes sense of parallel placement of plants producing ethanol and biodiesel on one platform. This allows to consider the features of crop rotation (rapeseed usually alternates with wheat); provide the flexibility of feedstock; cut the red tape at registration permits for production; allow the use of biodiesel for its own ethanol instead of methanol that is dangerous for the environment; reduce operating costs;

• to compare the advantages and disadvantages of each option of plant placing. The choice of the site depends on the availability of land measuring 4.8 hectares (buffer zone); the possibility of permitting state authorities for the construction of chemical manufacturing; availability of access to cheap raw materials (80% of the cost – the price of raw materials); availability of roads and railways that can provide minimum transport costs and ease of shipping products to the consumer; availability of water, electricity and labor;

• to provide the ensuring of technological flexibility of the plant. Biodiesel is still a new product that should gain more widespread. Therefore, it demands to change significantly, mainly because of problems related to the peculiarities of its use in transport.

Besides, the consumer may impose additional requirements to those which are set out in the regulations;

- to get real commitment from the major potential customers. To remember that long-term contracts for basic products can provide a significant rate of return;
- to analyze the possibility of pre-processing of raw materials, pay attention to the choice of catalyst and the problem of creating conditions for safety and for environmental safety.

Development and supply of biodiesel for production includes:

- Development of technical specifications;
- Approval of technical, technological and regulatory documents, technical specifications, technical conditions (TC), Standards of Organizations of Ukraine (JMA), State Standards of Ukraine (SSU);
- manufacturing and testing laboratory, research, research with industrial parties with signing the test reports;
- Acceptance of the work of state acceptance commission;
- training and development of production.

Some of these works can be combined and their sequence can be changed or complemented by other work. In this case, the manufacturer shall verify compliance of products with safety, health and environment. However, these requirements are often not respected. In particular, many companies have licenses to work with methyl alcohol. Often crude glycerol, which contains 15% methanol is poured on the field as "fertilizer". Certainly that way of biodiesel development has a lot of damage to the environment.

4.7. Features of Using Biodiesel as Motor Fuel

The use of biodiesel as a motor fuel reduces the emission of nearly all pollutants, namely hydrocarbon emissions in comparison to petroleum analogue are reduced by 56%, solids – 55, oxides of carbon – 43, nitro-gen oxides – 5-10, soot – 60%. The same amount of carbon dioxide is realesed.

In addition, biodiesel is subjected to virtually complete biological decay: microorganisms in the soil or water process 99% of biodiesel within 28 days, which helps to minimize the pollution of rivers and lakes. Esters of vegetable oils are well mixed with oil, diesel fuel, with no separation even in the presence of dissolved water.

Among other positive qualities of biodiesel, the following should be included:

- high-quality lubricating properties, which traditional fuel doesn't have after removing sulfur compounds;
- higher cetane number (at least 51);
- high ignition temperature (above 150°C), making biodiesel relatively safe;
- completeness of combustion due to the presence of 10% oxygen;
- a significant (60%) increase of engine life. In the Guinness Book of Records in 2005, it has been noted a truck that drovemore than 1.25 million km on B100 biodiesel without the repair of original engine .

Biodiesel also has drawbacks, such as:

- lower energy power and more high specific hourly consumption compared with petroleum fuel. As the heat of combustion of biodiesel is lower than normal (37.8 and 42.7 MJ/kg, respectively), it needs of the volume more than 9% (or 15% by weight). An average 1 liter of biodiesel is equivalent to 0.9 liters of conventional diesel fuel;
- relatively high temperature of turbidity. In the cold season it is needed to heat fuel coming from the fuel tank to the fuel pump or to work on fuel mixes with permissible content of biodiesel;
- aggressiveness regarding rubber parts;
- not suitable for all engines.

Possible failure of the engine and fuel system when working on biodiesel is given in Table. 4.6.

Table 4.6

Possible Failure of the Engine and Fuel System When Working On Biodiesel

The components and fuel properties	Action	Malfunction
Methyl esters of fatty acids	Causes drying, hardening and destruction of rubber products entering the engine oil	Fuel leaking. More frequent change of engine oil
Free methanol	Corrosion of aluminum and zinc	Fuel system corrosion. The low flash point in a closed chamber
Free water in fuel	Convertion of methyl esters ofvegetable oil in fatty acids. Corrosion. The increase in electrical consumption, the growth of microorganisms	Clogging of filter. Corrosion of fuel injection equipment

Free glycerol	Corrosion of nonferrous metals. The formation of sediment on moving parts and refinishing	Clogging of filter. Clogged nozzle fuel injectors
Mono and diglycerides	Same as glycerol	
Free fatty acids	Formation and accelerate the corrosion of zinc. The formation of salts of organic acids. The formation of organic compounds	Corrosion of fuel injection equipment. Clogging of filter. The postponement of sediment on the details
Density increasing	Increasing of fuel injection pressure	Fuel system minifying
Greater viscosity at low temperature Deterioration of fuel injection. The need for depressor additive	Stricter conditions of working of high pressure fuel pump. Increasing the depreciation of components.	Increased wear of components. Deterioration of fuel injection. The need for depressor additives
Solid particles	Deterioration of lubricating ability	Reducing the resource of fuel equipment
Formic acid and acetic acid	Corrosion of metal parts	Corrosion of the fuel equipment
Macromolecular organic acid	The same as free fatty acids	Corrosion of fuel injection equipment. The postponement of sediment on the details.
Products of polymerization	The postponement of sediment, especially in mixed fuels	Clogging of filter
Phosphorus	Disable of neutralizations and catalyst of exhaust system	Failure, reducing the environmental safety of waste gases

Minor costs for adapting the vehicles to use biodiesel in conventional engines using existing systems maintenance, transport and refueling promote its successful application in agriculture.

Table. 4.7

Comparative Characteristics of Vegetable and Mineral Diesel Fuel

Indicators	Refined vegetable oils					Diesel fuel
	rapeseed	sunflower	soybean	cotton	palm	
Density, kg/m3	924	923	915	916	913	839
Viscosity mm2/s at 20°C	63	25	77	84	-	4
The lower calorific value, MJ/l	36	39	37,2	34	38	42
Cetane number	32	21	41	41	-	50

Flash point,°C	320	220	305	318	295	60
Pour point,°C	-16	-11	-18	-4	-8	-22
Sulfur content,%	0,005	0,005	0,005	-	-	0,5

Table 4.8 shows the elementary composition of rapeseed oil and diesel fuel.

Table 4.8

Elemental Composition of Rapeseed Oil and Diesel Fuel

Indicators	Carbon	Hydrogen	Oxygen	Sulfur
Rapeseed oil,%	78,3	12,8	8,8	0,005
Diesel%	86,4	12,1	95	0,5

As it can be seen from Table. 4.8, the elemental composition of rapeseed oil, compared to diesel fuel, carbon and sulfur content is much lower. The biggest difference is a relatively high oxygen content in rapeseed oil, while this element is missing in the diesel fuel.

Now it has been developed a number of processes of biodiesel production from vegetable oils. Based on the analysis, three operations are required in all known technologies of biodiesel preparation: preparation of a mixture of catalysts; mixing vegetable oil with a mixture of catalysts; separation from vegetable oil glycerin obtained as a result of a chemical reaction. One of the most complex operation is the mixing of vegetable oil and catalysts.

The simplest and most affordable way to use rapeseed oil is the dilution with diesel fuel. An experimental research of domestic and foreign scientists establish es that with increasing content of rapeseed in biodiesel, the blends time of combustion increases, and when the oil content is more than 60%, the combustion process does not have time to finish before the opening of the exhaust valve of the engine. To reduce the total time of combustion of biodiesel, combustion mixture is injected by activators (such as organic compounds of iron – Ferrocene).

Biofuels from rapeseed oil used as a motor fuel in two versions: a mixed fuel consisting of a mixture of rapeseed oil with diesel fuel; as rapeseed oil methyl ester.

The blended fuel has the following advantages: simple technology which is implemented in farms without significant cost; while maintaining high stability; solubility at the molecular level.

Comparative physical and chemical characteristics of rapeseed oil and mixed diesel fuel are shown in Table. 4.9.

Table 4.9

Comparative physical and chemical characteristics of fuel

Indicators	Rapeseed oil	The mixture of oil and diesel fuel (25:75)	Diesel fuel (GOST 305-82 L/3)
The lower calorific value, MJ	37,2	38,3	41,8
Density, kg/m3 (20°C)	915	890	860/840
Viscosity mm2/s (20°C)	78	38,2	3,6/1,8-5
Clouding temperature,°C	-9	-9	-51-25
Pour point,°C	-18	-16	-10/-35
Cetane number	41	42	45
Iodine number, g/100g	9,7-10,3	9,0	6,0
Acidity, mg KOH/100sm3	6,1	6,0	5,0
Flash point,°C	593	583	543
Content by weight, %:			
Carbon	78,3	80,3	86,4
Hydrogen	12,8	12,9	12,1
Oxygen	8,896	56,52	0
Ability to 10% of the balance, % max	0,43	0,4	0,3
Mass fraction of sulfur,%	0,05	0,16	0,5
Content of actual tar mg/100 cm3	-	-	40/30

In comparison with diesel fuel, the pure rapeseed oil density is higher by 9%, viscosity at is higher by 25 times, the sulfur content is less by 10 times. In pure rapeseed oil pour point is higher by 17°C, compared with winter fuel and at 10°C lower than summer diesel fuel. Blended fuel for physico-chemical parameters occupies an intermediate position.

The higher viscosity of pure rapeseed oil complicates its use in engines, but when the temperature rises to 70-90°C its viscosity is reduced to values that are close to the viscosity of diesel fuel.

The rapeseed oil methyl ester (ROME) on its physicochemical characteristics (viscosity-ash) is closer to the diesel fuel. Using ROME does not need heating fuel, less deposits are formed on the parts of cylinder-piston group. ROME quality is standardized by European standard EN 14.214.2003 (E).

When it is given that the mixed fuel energy output for the fuel component is more than ROME, and taking into account simpler and cheaper technology to obtain it, the comprehensive experiments on mixed fuel with different content of rapeseed oil were carried out on the engine D-240 Minsk Motor Plant. When the engine working on biofuel with oil content of 0 to 100%, it has been found that the optimal composition of mixed fuel with workflow parameters equals to the content of 75% rapeseed oil.

The analysis of the environmental performance of the engine indicates a decrease in toxic emissions when running on biofuel. Carbon monoxide CO (carbon monoxide) in all modes of loading has being reduced in twice as hydrocarbons CH. The number of particulate matter (opacity) at maximum load is less in twice too, opacity regulations on small load drops to 0. The exceptiona is NO_2 nitrogen oxides, emissions for which (on the maximum load when running on biofuel) are increasing by 8%. This is obviously due to the presence of bound oxygen in biofuel.

The adapting of fuel energy system means that in order to work on mixed fuel regarding the establishing of a small-sized extra fuel tank for diesel fuel needed to start and warm-up the engine at low temperatures. It is also needed to install a 3-way valve to switch from one fuel to another.

Figure 4.9 shows the scheme of fuel system adaptation to work on mixed fuel.

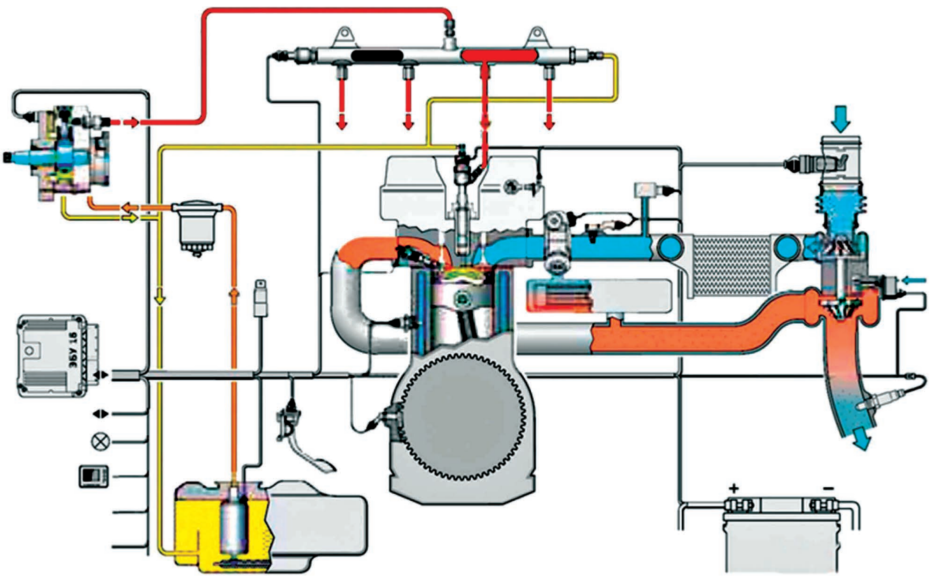


Figure 4.9. Scheme of Fuel System Adaptation to Work on Mixed Fuel

Moscow State Agro-Technical University named after V. P. Horyachkina conducts experiments on replacing diesel fuel with biodiesel blend (with a ratio of components 1:1). According to studies, engine environmental characterictics are being improved significantly. Emissions of nitrogen oxides at the rated speed of the engine are reduced by 15-20%, soot – by 30-35%, carbon monoxide and hydrocarbons – by 10-15%.

To establish the physical and chemical characteristics of the blends of biodiesel with diesel fuel the series of tests on the engine been done. The purpose of these tests was to identify the impact of biodiesel additives in diesel on characteristics of blends and performances of the engine. The tests were conducted with a biodiesel content of 10 to 50% and from 50 to 100%. With increasing biodiesel additives in diesel fuel, density, viscosity and flashpoint in closed crucible are increasing. Table 4.10 shows characteristics of compounds and the results of their tests.

Table 4.10

Physical and Chemical Properties of Biodiesel Blends of Diesel Fuel and Engine and Tests Results

Indicators	Biodiesel and diesel mixture										
	100:0	90:10	80:20	70:30	60:40	50:50	40:60	30:70	20:80	10:90	0:100
Fuel content:											
-C	0.77	0.780	0.790	0.80	0.810	0.820	0.830	0.840	0.850	0.860	0.87
-н	0.12	0.121	0.121	0.122	0.122	0.123	0.124	0.124	0.125	0.125	0.125
-0	0.11	0.099	0.089	0.078	0.068	0.057	0.046	0.036	0.025	0.015	0.004
-с/н	6.42	6.47	6.52	6.57	6.62	6.67	6.72	6.76	6.81	6.86	6.90
Kg of air/kg of fuel	12.62	12.81	12.99	13.17	13.35	13.54	13.72	13.90	14.09	14.27	14.45
Density (20°C) g/cm3	0.885	0.878	0.873	0.868	0.862	0.858	0.852	0.847	0.842	0.835	0.83
Viscosity (20°C), mm2/s	7.62	6.84	6.46	6.04	5.64	5.04	4.98	4.69	4.38	4.22	4.00
Flash point,°C	173	150	110	100	90	90	90	85	85	80	80
Lower warmth combustion MJ/kg	37.20	37.72	38.24	38.77	39.31	39.86	40.41	40.97	41.54	42.11	42.70
The test results of diesel with a power of 2 kW and E = 10°to the top deadlock											
efficiency coefficient	0.239	-	-	-	-	0.236	0.235	0.239	0.237	0.235	0.238
To,°C	357	-	-	-	-	336	331	327	335	337	337
Tк,°C	587	-	-	-	-	546	540	511	506	499	488
NO2	507	-	-	-	-	444	433	-	420	417	395

During numerous comparative tests, the maximum increase of engine ef-ficiency when running on biodiesel (compared to diesel fuel) was about 6%, which is consistent with the results. Increased concentrations of bio-diesel mixed with diesel fuel improve engine efficiency, reduce opacity, but increase the excretion of nitrogen oxides.

To reduce excretion of nitrogen oxides, adjusting the angle of advance fuel injection can be used. The variation of engine efficiency can recommend re-ducing the angle of injection as a way to reduce the release of nitrogen oxides when running on biodiesel to maintain better efficiency than with diesel fuel.

Table. 4.11 shows some types of agricultural machinery that is adapted to run on biodiesel

Table. 4.11

Types of Agricultural Machinery Adapted to Work on Biodiesel

Firm	Type	Features
Case	Tractors	All engines have benn produced in series since 1971, but you should pay attention to the manufacturer's recommendations
Claas	Agricultural machinery	Grain and forage harvesters from the factory, the new edition
Fendt	Tractors	Recomplete set of equipment is possible, new tractors are admitted
John Deer	Tractors, harvesters	General admissibility issue since 1967
Massey	Tractors	All tractors produced after 1976, without restrictions. It is recommended to change oil at low load at least once a year
Nersedes	Tractors	All tractors since 1988 model year
New Holland	Prime mover	All tractors last years release and combines and self-propelled mowers
Lamborghini	Tractors	All since 1980 model year
Deutz-Fahr	Engines	All engines in 1015 model line is not permitted, possibly making the order. Intervals of replacing oil are reduced by half. Engines with a high load are not recommended to run on biodiesel. In series engines, fuel hose and the fuel pump is resistant to the use of biodiesel, encouraged their annual replacement

The use of methanol as a fuel for diesel engines is very attractive. This is due to the availability of raw materials, the production and relative cheapness of methanol. If gasoline engines using methanol as an additive to gasoline

(15%) is not a problem, then the use of methanol in diesel engines has problems. The main reason is that no special diesel fuel additive is not mixed with methanol, which makes it impossible to supply a mixture of diesel fuel into the combustion chamber.

One can cite several ways to use methanol in diesel:

– Direct feed into the intake pipe;

– Supply of methanol conversion products (CO and H J in the inlet pipe after reactor (thermal or catalytic thermal);

– Feed directly into the combustion chamber.

The first method does not provide a large positive effect, the second is complex. The third the requires improving the fuel equipment. This is because methanol has a low cetane number (less than 5) than diesel fuel cetane number (45-50), which makes it difficult to spontaneous combustion chamber diesel.

Therefore, to ensure the proper combustion, a proper dose incendiary fuel, such as diesel fuel should be used. This requires the use of two fuel systems: the first – for the supply of methanol, the second – for the supply of fuel ignition.

Another way of feeding the methanol into the combustion cham-ber using serial fuel equipment is proposed.

Methanol is used in the production of biodiesel and dissolve in it for a certain concentration. A study was conducted to determine the maximum concentration of methanol in biodiesel without a trial separation and feeding the methanol into the intake pipe and combustion chamber in a mixture of biodiesel. Getting bundle assessed visually the appearance of the interface. The study found that the separation of mixtures of methanol to biodiesel occurs at 25% methanol and 20% when the content stratification occurs in about 30 days. In this case dehydrated methanol should be used. You must also consider the fact that absorption of moisture subsequently occurs from the atmosphere, leading to the separation of mixtures.

Characteristics of compounds and test results are given in Table. 4.12.

With the increasing proportion of methanol the density, viscosity and flash point in closed crucible decreases.

When a methanol is put directly into the intake pipe, we can see an increase of rigidity and a sharp deterioration in engine efficiency at low concentrations of methanol (the ratio of methanol to diesel fuel 0.35%). However, the engine works fine when the concentration of methanol in the mixture of biodiesel is 15%. Operating the vehicle with a diesel engine on a mixture of such complaints did not lead to the traction of motor.

Table 4.12

Physico-chemical properties of biodiesel blends of methanol and the results of tests on diesel

Indicator	Methanol: BIO ECT										
	100:0	20:80	15:85	10:90	5:95	1:99	0.5:99.5	0.4:99.6	0:100	10:90	0:100
Fuel composition:											
-C	0.375	0.691	0.711	0.731	0.750	0.766	0.768	0.768	0.77	0.860	0.87
-н	0.125	0.121	0.121	0.121	0.120	0.120	0.120	0.120	0.12	0.125	0.125
-0	0.5	0.188	0.169	0.149	0.130	0.114	0.112	0.112	0.11	0.015	0.004
-с/н	3.00	5.71	5.89	6.06	6.24	6.38	6.40	6.40	6.42	6.86	6.90
Kg of air/kg of fuel	6.522	11.40	11.71	12.01	12.32	12.56	12.59	12.60	12.62	14.27	14.45
Density (20°C) g/cm3	0.79	0.863	0.870	0.875	0.879	0.882	0.883	0.881	0.884	0.835	0.83
Viscosity (20°C). mm2/s	1.84	4.13	4.53	5.16	5.92	6.94	7.09	7.16	7.45	4.22	4.00
Flash point.°C	8					40	55	61	173	80	80
Lower warmth combustion MJ/kg	19700	34004	34816	35619	36414	37043	37122	37137	37200	42.11	42.70
The test results of diesel power at 2 kW and t 19°to the top point											
efficiency coefficient	-	-	0.236	0.236	-	0.232	-	0.234	0.25	0.235	0.238
To.°C	-	-	289	300	-	298	-	297	298	337	337
Tк.°C	-	-	521	489	-	528	-	533	568	499	488
NO2			747	676		765		804	845	417	395

It was revealed a general trend, that with increasing concentration of methanol in the mixture of biodiesel the engine deteriorates efficiency, but it reduces harmful emissions of exhaust gases. When adding the 10% methanol, nitrogen oxides are reduced to 30%, opacity to 40%. The reduci ng NO_2 may explain the decrease in local temperatures, evaporation of methanol as the temperature is high. This confirms the decline of the temperature in the combustion chamber. It is noted that this method has some difficulties when transferring diesel engine because the filter is blending a mixture of diesel fuel. Also, there is separation, leading to engine stall. Before the change, the mixture must be completely drained from the fuel system of the engine.

Herbal additives. Additives are widely used for various purposes in engines, i.e. in order to improve fuel efficiency and environmental performance.

The use of well matched additives with the required concentration leads to improve the performance of the engine, increasing its efficiency, reducing emissions of exhaust gases. However, the same additives mixed with fuel of plant origin, including vegetable oils have no such action.

In response to a request in this regard the company LIQUI MOLY GmbH (Germany) was recommended to increase the concentration of additives. Even increasing the concentration of additives does not always improve the performance of the engine. In some cases, there is their deterioration.

We also use terpenes (plant substances that are derived from coniferous trees as additives). The results of tests of diesel fuel mixed with pine oil (terpene alcohol content of 75%) are in the range of 0,05-0,2 wt. %. The addition of 0.2 wt. % pine oil in diesel fuel when running on diesel generator 1DT12T helped to improve the engine efficiency by 4% and reducie NO_2 by 33%, aldehydes – by 83% and CO_2 by 21%. It has been suggested that the addition of terpenes (turpentine) to a mixture of vegetable oil with diesel fuel combustion will provide improvements in the chambers of engines.

Nutritious turpentine (oil terebinthine) is a product of pine resin processing that has a flash point of 34°C and the ignition temperature of 300°C, which is lower than in the vegetable oil and diesel fuel.

During the study, there was a complete dissolution of turpentine mixed with various vegetable oils. To test the possibility of using turpentine as additives to oils, it has been prepared mixture of this composition: turpentine – 5%, sunflower oil – 10%, soybean oil – 5%, corn oil – 5%, mustard oil – 5% and diesel fuel – 70%. The test results are shown in Table. 4.13.

Table 4.13

Physical and Chemical Characteristics of Compounds with the Addition of Turpentine and the Results of Tests on Diesel

Indicator	DF	Turpentine, sunflower oil, soybean oil, corn oil, mustard oil, diesel fuel – 5:10:5:5:5:70	turpentine and diesel fuel – 30:70
Specifications of fue			
Density g/cm3	3.832	0.854	0.839
Viscosity mm2/s	1.14	7.95	3,4
Flash point in closed crucible,°C	35	80	67
Lower combustion, kJ/kg	42700	40990	40990
Results of testing 1,64 kWt			
efficiency coefficient	0.223	0.222	0.221
T,°C	254	254	258
Air excess ratio	2.31	2.35	2.35
CO_2, %	4.73	4.17	6.42

Fig. 4.10 shows the changing engine efficiency when working on sharp fuels of vegetable origin.

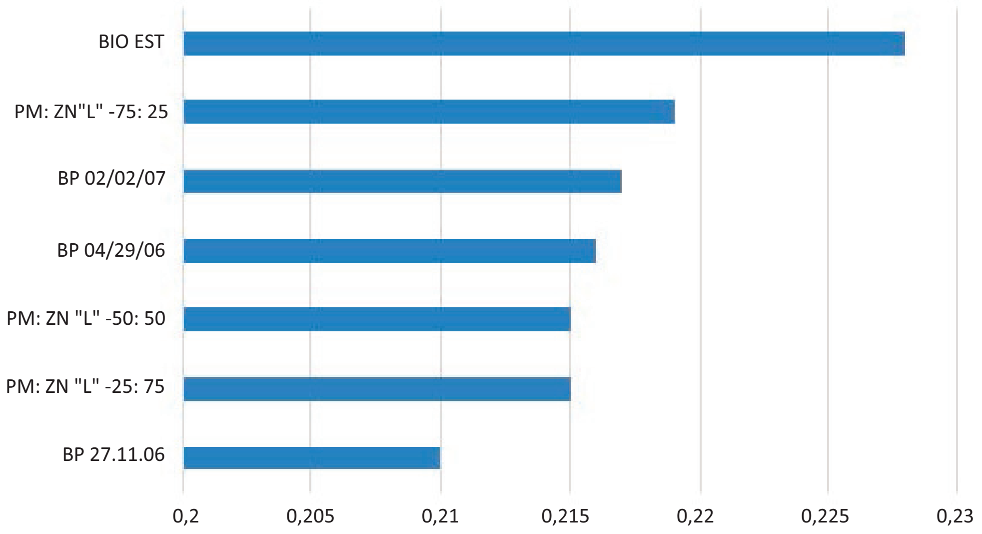


Figure 4.10. Changing engine efficiency when working on sharp fuels of vegetable origin

BIO EST – biodiesel from soybean oil; BS (02/02/07) – biodiesel from vegetable oils and date of receipt; CO SE "L" – 25:75 – a mixture of vegetable oil with diesel fuel mark «L» in the proportion of 25% to 75%. Net calorific value taken for biodiesel, vegetable oil and diesel fuel respectively 37200, 37000 and 42700 kJ/kg.

Table. 4.14 shows the comparative characteristics of the subject mark «L» Est Bio and biodiesel standard EN 14214.

Table 4.14

Physical and Chemical Characteristics of Fuels

Specifications	Diesel DSTU3868-99	Biodiesel BIO ECT, PE «Khimpostavschik»	Biodiesel EN 14214 (Europe)
The density p (20°C) g/cm3	0.831	0.884	-
The density p (15°C) g/cm3	-	0.887	0.86-0,9
Viscosity (20°C), mm2/s	4	7.3	-
Viscosity (40°C), mm2/s	-	4.73	3.5-5.0
Lower combustion, kJ/kg	42700	37200	--
Cetane number	45	51	51 min
Flash point in closed crucible,°C	80	173	120 min
Clouding temperature,°C	-12	-3	
Pour point,°C	-24	-5	
Iodine value, d (12/100 d)	1	129.5	120 max
Water content mg/kg	-	300 mg/kg	500 max
Phosphorus content mg/kg	-	9	10 max

One of the drawbacks of traditional biodiesel is a high pour point. Currently conducted research for finding additives that would ensure reduction in freezing temperature to an acceptable level will use biodiesel as all-season fuel.

For consumers, the use of a fuel of vegetable origin should be determined by economic expediency at any time. The consumer has to decide what it profitable: to use biodiesel in existing engines or after redesigning of the engine, to design combustion chamber or use unrefined oil. The results show that the widespread use of mixtures of different types of fuel is possible. This may be a mixture of biodiesel with diesel fuel. It should be noted that even a small proportion of biodiesel (5-10%) can have a positive impact on efficiency and reduce of engine smoke. The quality of biodiesel is of great importance.

The presence of oil-plant additives in blends improves the engine efficiency, reduces smoke, but increases the amount of nitrogen oxides that may be offset by a decrease in the angle of fuel injection.

The dynamics of changes in smoke and nitrogen oxides is more favorable to mix with herbal fuel than with diesel fuel. Another way of simultaneously reduce of nitrogen oxides and smoke can be to add methanol into biodiesel, but in this case the engine efficiency deteriorates.

4.8. Biodiesel from Algae as Third Generation Biofuel

Algae are versatile organisms that have no real root or leaves. Unlike plants, algae don't consume water and nutrients through the roots and do not release them through evaporation with leaves. There are technologies that allow to grow algae not only in the open water, but in the closed bioreactors. In a closed system, algae require 99% less water than any other culture.

The closed bioreactor system can be assembled in various configurations – horizontal or vertical, different shapes and sizes, with controlled parameters of cultivation. The culture fluid is periodically centrifuged from bioreactors for algae biomass discharging. It is enriched with triglycerides of fatty acids and carbo-hydrates. Isolated from algae biomass by transesterification, triglycerides converted into biodiesel, and carbohydrates – into bioethanol.

As a raw material for biodiesel, microalgae heeds special attention. Microalgae are the fastest growing plants on the Earth. They grow in 100 times faster than trees. Specific strains of microalgae contain up to 70% of lipids (fats) in the dry mass.

The most common type of algae that are used for industrial cultivation is natural strains of unicellular algae Chlorella type, growing in virtually all climatic regions, but with different rates of growth rate. The biomass of algae consists of an average of 50% of the triglycerides, 25% of carbohydrates and 25% of protein.

The have been developed environmentally friendly extraction processes with carbon dioxide in a critical mode. Such extraction provides almost 100% ex-traction of oil from algae.

The production of carbon dioxide and ethanol as the main raw material for this technology is accompanied by the formation of a significant amount of carbon dioxide (4-5 kg per 1 dl of alcohol), the integration of algae cultivation and bio installation is very promising in terms of distillery. In addition, the distillery uses a significant amount of industrial water for cooling in industrial processes, including a sufficient temperature for the cultivation of algae. Thus algae can be used for clean production of biofuels (ethanol, biodiesel), which will be attractive for investors.

For algae growth it is necessary to maintain consistently high temperatures, so the production should be placed near power plants, because it allows covering 77% of the heat demand. This technology does not require a hot desert climate for the cultivation of microalgae.

In the process of growing, microalgae can accumulate fats for further processing into biodiesel and simultaneously clean polluted water. Considering the economic efficiency, the most promising areas of algae usage are wastewater treatment of the food industry, breeding farms, cattle farms, poultry farms, slaughterhouses.

The remains of algae, obtained after the production of biofuels can be used in pharmacology, production of animal feed and for processing organic fertilizer.

The Research in the field of microalgae cultivation and processing them into biofuel has been successfully involved in such countries such as the US, Japan, Bra-zil, Portugal, Iran and others.

In 2013, Solazyme Company, engaged in the research in the field of microalgae and commercial production of biodiesel, sent a plane Boeing 737-800 from Houston to Chicago, filled up with a mixture of traditional fuel for aircraft and biofuels derived from microalgae.

Iran began experimenting with the production of biofuels from algae in the early 2000s. Scientific studies show that the south of Iran is the most promising area in the world for growing algae due to the high humidity, sunny weather and the presence of salt water. The commercial production of biofuel from algae in Iran began in 2015.

The Israeli company Seambiotic has offered the technology of industrial cultivation of seaweed using carbon dioxide, which is released together with the emissions of power plants. Instead of polluting gases (which is a major cause of global warming), they undergo a process of filtering through the pool, where microscopic algae live, and then are used to produce biofuels. This technology makes it possible to utilize excessive carbon dioxide emissions and reduce pollutants entering the atmosphere.

The US Department of Energy studied the algae with high oil content program "Aquatic Species Program" for many years. The researchers concluded that California, Hawaii and New Mexico are suitable for industrial production of algae in open ponds. During 6 years, algae are grown in the water area of 1000 m^2. Grown in ponds of New Mexico, algae showed yield increase by more than 50 grams of algae per 1 m^2 per day. The energy sufficient to annual demand of 5% of the US cars can be produced on 200 000 ha, this area – is less than 0.1% of the US land suitable for cultivation of algae. The technology still has plenty of difficulties for mass implementation. For example, algae need high temperature for growing them in a favorable desert climate, but requires some regulation of the temperature at night drops in temperature. So, Corporation GreenFuel Technologies (USA) has developed a technology for growing algae Emissions-to-Biofuels, which operates on the emissions of power plants (CHP).

Clear bulbs where algae are being grown and feeded on used in this work cycle bioreactor. In addition to algae and water, nutrients such as plant remains are added. Smoke gas or other gas streams enriched with CO_2 are passed through a bioreactor by a fan. The gas optimizes the growth of algae, which begin to spawn. The part of biomass derived from the bioreactor and is primary dry. After the final dewatering, biomass is ready for further processing. Water that is released after dewatering algae, is returned to the bioreactor with a little cleaning to prevent sediment flux salts.

This process allows to obtain alcohol, biodiesel, high-quality animal feed, and other by-products. The industrial plants can produce up to 80 tons/hectare of algae a year. This process significantly reduces smoke emissions CHP: NO_2 – 86% and CO_2 – up to 40%.

In Australia, in 2013, a pilot project on microalgae cultivation and processi ng it into biodiesel was introduced. The project cost amounted to $ 3.5 million.

Thus, compared to the other energy crops, the benefits of biofuel from algae are the following: algae cultivation does not harm water resources and the environment; they can be grown in polluted waters; it is best to grow algae in seawater, which is actually an inexhaustible resource; algae contain lignin and cellulose that improves the process of converting raw materials into biofuels; they contain large amounts of polyunsaturated fatty acids, which allow biodiesel do not lose qualities of the fuel at low temperatures, therefore diesel engines on this fuel can work in cold conditions; algae can produce 300 times more oil per a unit of area than conventional oil crops such as rape, palm, soya or jatropha. The duration of algae cultivation is from 1 to 10 days, which allows to collect several harvests in the short term.

Today, the production of biodiesel from algae on an industrial scale is not very effective, but the rapid development of technology in this field indicates the promising area of production of this fuel in the future.

4.9. Prospects for Biodiesel Production in Ukraine

Ukraine's lack in traditional energy sources, the increase of pollution encourages the scientific community to seek for new clean fuels. One of these areas is the production of diesel fuel from vegetable oils.

In the past three years, the average annual consumption of diesel fuel in Ukraine is about 6.5 million tons, and, according to the Energy Strategy of Ukraine approved by the Cabinet of Ministers of Ukraine, it should be increased to 7.7 million tons by 2030.

In order to ensure the carrying out of agricultural work on technological standards, around 1870 thousand tons of diesel fuel and 620 thousand tons of gasoline should be produced each year. About 4.5 million tons of oil, mostly imported are used so produce this amount of fuel. Due to the fact that the steady growth of its value leads to an increase in the cost of petroleum products, and conse-quently, agricultural products, the traditional option to meet the needs of agricul-tural production due only to petroleum products is unpromising.

It is more efficient to provide agricultural producers with biofuels, produced from vegetable oil. In favor of these options, there is an experience of such countries as Germany, France, Austria, the Czech Republic, where rape is used for growing 10-14% of arable land.

In Ukraine, there are national standards for diesel fuels that meet European standard EN-590-93 and part of the standard EN-590-2000. As a member of the Geneva Agreement since 1999, Ukraine applies the rules of the UN EEC on mandatory certification of vehicles with diesel engines.

The main environmental requirements for diesel fuels consist of the following:

- content of aromatic hydrocarbons, especially toxic polycyclic hydrocarbons;
- sulfur compounds to thousands of percent;
- emission products of incomplete combustion, carbon monoxide, hydrocarbons, particulate matter and nitrogen oxides. In connection with Ukraine's ratification of the Kyoto Protocol (it concerns problems reducing greenhouse gas emissions), the question of carbon dioxide reduction by road transport in the atmosphere is updated.

In Europe, biodiesel is mostly made from rapeseed. There are several options to use this plant for the production of biodiesel. The main among them are the following:

The first direction is receiving crude oil and its careful filtration. The engine runs on pure rapeseed oil. This option is chosen by experts in Germany, creating special motors or structurally modifying traditional ones. Under this option, biodiesel is used mostly by farmers for their own equipment. So farmers or farmer's cooperatives jointly grow canola, the cropping area of which reaches 10-12% of arable land. Low-power private facilities produce 300-3000 tons of biofuel per year. In 2001, the government provided each farmer with subsidy of 360 euros per hectare with rape growing for biofuel. The preference is given to vehicles adapted to work on biofuel. First of all, it is used in the areas of intense ecological state (public transport, shunting locomotives, vehicles that run on reservoirs with limited water exchange).

Germany made some domestic brands of diesel engines that are run on pure rapeseed oil. The main suppliers of these engines are such producers as "Deutz Far" and "Elko" (nine units). Today Germany provides more than 5% of its needs in diesel fuel with rapeseed oil.

The second direction is to obtain crude vegetable oil and its careful filtration and centrally regulated addition of pure oil (5-40%) to trade diesel. You do not need to create engines adapted to rapeseed oil. The main consumer of biofuels is marine, naval and road transport. In particular, municipal buses, the work of which is prohibited in some major cities and if they use traditional hydrocarbon fuels. Thus the penalties for failure to comply with the emission of toxic substances exceed the cost difference of biological and petroleum diesel. Based on this scheme, biodiesel, is produced mainly centrally on powerful units in the amount of 10.500 tons/year in such countries as France or Italy.

The third direction is getting rapeseed-methyl ester (RME) – the product of relatively simple catalytic synthesis from rapeseed oil and methanol. In the reaction of reestrefication of oil, fats react with methyl (ethyl) alcohol in the presence of a catalyst (lye), resulting in the formation of esters and glyserol phase. Biodiesel can be used in any diesel as pure (in adapted engines) and mixed with diesel fuel.

This option is chosen by most of the EU Member States. It is in focus for Ukraine today too. It should be noted that the RME is used in Belgium, Italy, Germany, Sweden, France and other European countries. These esters are added to the commodity diesel fuel in concentrations of 20-30% without additional structural modifications of the engine.

The department of homogeneous catalysis of Institute of Bioorganic Chemistry and Petrochemistry of NAS of Ukraine conducted research on mandatory 5-25% of RME additive to summer diesel fuel domestic trademarks. The tests completed on stationary engines 148.5/11 and YMZ-236 have shown that the use of this fuel reduces the emissions of hydrocarbons and $C0_2$, while the rate of formation of nitrogen oxides is not changed. However, it is also noted some increase in emissions of so-called ozone depleting components: aromatics, olefins and aldehydes. It was also found coking of injectors spray of fuel system (typical for RME content 15-25%). To solve this problem, the Institute developed iron-additive IBONH-2 based on domestic feedstock. One-time use of additives in the composi- tion of mixtures of biofuel (0.2% wt.) makes it possible to completely clean spray nozzles of diesel engines. Besides, it is characterized by antiscale and antismoke additive properties. It is important that the presence of RME (10- 25%) improved lubricating properties of low sulfur-containing (so-called clean) diesel fuel L-0, 10-40 per GOST 3868-99. This is a unique circum-stance because the reduction of sulfur compounds in hydrocarbon fuels causes significant loss of its lubricating properties of friction pairs precision plunger fuel pumps.

Because of the need for efficient use of biofuels in the energy balance of Ukraine. The Law of Ukraine № 1391-XIV "On alterna- tive types of liquid and gas fuels" was adopted in January 2000. This law defines the legal, social, economic, environmental and organizational principles of production and consumption of alternative liquid and gaseous fuels based on the involvement of unconventional energy resources and aims to create the necessary conditions for the expansion of production and consumption of these fuels in Ukraine. In December 2006, the Cabinet of Ministers of Ukraine approved the Program of development of biodiesel production.

It is assumed that implementation of the program in full will help to bring biodiesel production to 623,000 tons per year, which will reduce oil imports to 1.88 million tons and therefore reduce the cost of foreign exchange resources of more than 4.5 billion USD.

It can bring additional revenues to the state budget from payment of VAT for the implementation of 623,000 tons of biodiesel and other taxes to the state and local budgets with amount about 1 billion USD.

In May 2009, the Parliament of Ukraine adopted the Law of Ukraine "On amendments to some laws of Ukraine to promote the production and use of biofuels". The law stipulates that the activities in the production and use of biofuels may be done by entities of all forms of ownership in accordance with the laws of Ukraine.

Entities that use different technologies of biofuels production, have equal rights to access to the market of biofuels. If the body, which is charged with implementing the requirements of the law, does not level the nature of his ar-ticles, biofuel production in Ukraine will grow rapidly.

In Europe, considering the real possibility of growing oilseed crops for energy use, the priority position belongs to rapeseed oil and sunflower oil holds the second position. In some European countries (Austria, Germany, France) and the leading enterprises of Ukraine, rape yield riches up to 400 kg/ha, which makes it possible to obtain about 1.5 tons of oil from 1 ha of cultivated area.

In Ukraine, rape is not an exotic culture. By 1910 our agricultural land under this crop had amounted for 30-40 thousand hectares of arable land. Oil was taken from it with own technology for food and industrial purposes (sunflower then was planted on a much smaller area). In the late 30's, the main commodity of rape crops, mostly winter varieties, were formed in the regions of Western Ukraine, Polissia and Forest-steppe – 120-130 thousand ha. Then it started to rapidly reduce cultivation and by the end of the 50's rapeseed areas went down to a minimum.

The rape production sector in Ukraine at this stage continues to operate on an extensive basis. Yields of winter rape is only 30% of the potential and 40% of the average, spring – accordingly 20-25 and 25-35%.

The western Europe has accumulated some experience in the industrial produc-tion of pure rapeseed oil and synthesis on the basis of rapeseed-methyl ester (RME). This contributes to building large centralized processing facilities; placing small production fascilities at agricultural and other companies.

Let's consider a few options of biodiesel cost depending on the capacity of refineries.

Option 1. Construction of plants for biodiesel production with capacity of 50-100 thousand tons per year. With this power, there is need to process about 300 thousand tons of rapeseed, which may grow under yield conditions of 15 kg/ha in the area of 100-120 thousand ha. This will cause a problem of crop delivery of and the use of rapeseed meal and while viewing rotation.

It is estimated that the production of biodiesel from rape at power plant with mentioned capacity could be profitable if the price is 2,000-2,300 UAH/t and under the condition that its production will be established for the integrated use of primary and by-products of closed cycle – from feedstock production to the release and use of biofuels from rapeseed yield not less than 20 kg/ha and the use of rape as an animal feed, the use of straw for economic and energy needs and glycerin as a by-product output.

In terms of obtaining maximum economic efficiency of biodiesel, it is necessary to create regional zones of concentrated rape growing at a defined volume of cultivated area, build the infrastructure (agrarian technical service systems, a new generation of elevators, feed mills, etc.) and develop animal husbandry.

Our calculations show that the cost of biodiesel production at plants with a capacity of 50-100 thousand tons a year will always be high and biodiesel prices for consumers without state subsidies are mostly unprofitable, if it does not take economically reasonable distance transportten of crops, ensures the realization of collateral products, carries out contingencies for technical and engineering services and more.

Option 2. Let's consider the economic feasibility of building a plant for biodiesel production capacity of 5.7 thousand tons a year. The main advantage of these is that plantsthey can be supplied with equipment of domestic production, with lower cost than foreign. A major advantage is the fact that Ukrainian producers offer innovative technologies for the production of biodiesel, providing high quality biofuels which are significantly less in material consumption by 2-3 times less in energy to produce 1 ton of biodiesel. Such plant may be build on the basis of coproducers of rapeseed, providing farmers needs of one or two districts. In the production of biodiesel on a cooperative basis, when the plant comes on rapeseed regulatory and estimated cost, the cost of biodiesel production will more than double its value in lower purchases of rapeseed at market price. The founders with constructing plant, will be able to save running costs while en-suring 100% of biodiesel.

Option 3. The production of biodiesel directly on the farm for their own needs. In agricultural formations, which rapidly increasing production of rape, where the need for diesel fuel ranged from 200 to 400 tons per year, the production of this volume from their own harvest of rape is based on the use of domestic innovative equipment or if the farms oil extractive shops as transitional option, which enables to organize cost-effective production of biodiesel. At the same time, it is almost completely solved the problem of efficient use of rapeseed meal for livestock. It should be noted that these conditions are violated guidelines of scientists about the optimal ratio of rape in the rotation of a particular enterprise. This helps to preserve soil fertility as the main wealth of the country and is effective for use the renew-ble fuel in Ukraine – biodiesel.

Positive results in reducing production cost of biofuels reached the Western Europe through the establishment of corporate units for the production and processing biomass. Corporate enterprises as bioenergy producers and proces-sors of raw materials, profitably compete with traditional fuels with its independence from market conditions for fuel and lubricants, thanks to a closed technological biofuel cycle.

This association of enterprises in the regional corporation of closed technological cycle of biofuel production with the scheme "bio raw material – processing – biofuels – the realization of biofuels" and interconnected with well-established centralized production planning and funding of all works on the production of biofuels and bioenergy feedstock allows you to create the right conditions for stable operation of joint enterprises and reduce the cost of biofuels by placing these companies with performing corporate orders.

For such organization as a corporate formation of biodiesel production, it should combine these specialized businesses, creating effective cluster:

- agricultural enterprises for the production of rape, where this product is not main and the corporate formation orders for a number of commodity seed rape capacity that is used for corporate enterprises, processing seeds for oil;
- the enterprises processing seeds for oil, where the production of rapeseed oil for the enterprise should not be main, but only corporations order for a certain amount of oil to download corporate enterprises with biodiesel;
- producers, processing oil for biodiesel, where biodiesel is the main product.

The corporate formation plans the production of biodiesel in such way that allows mutual settlements between enterprises with stimulating the production of bioenergy feedstock, namely:

- to reduce the energy cost component of primary products of agricultural enterprises producing rapeseed, corporate producers of biodiesel, first of all, transfer part of its production (biodiesel) to an extent that would sat-isfy the energy needs of these enterprises;
- Processing enterprices shculed primarily provide rapeseed oil with its by-products – meal in the amounts covering feed needs of rapeseed producers.

The given integrated approach is aimed to resolve mutual problems while pricing for biodiesel makes it possible to significantly reduce the cost of the main components of biodiesel by achieving increased yields of rapeseed per 1 hectare of cropping area, reducing the cost of processing rapeseed into oil, reducing energy consumption for cultivation; the production excludes biodiesel, rapeseed refined products of food, feed, pharmaceutical and other directions.

In most regions of Ukraine, on the basis of complex multi-process lines the corporate producers and processors of raw bioenergy crops are able to bring the production capacity of economic entities of all forms of ownership and cultivation of high-energy crops and their processing. This will facilitate augmentation of land resources to produce bio raw material, creation and development of industrial infrastructure of rape seed production, infrastructure, production of rapeseed oil, biodiesel and infrastructure use of biofuels in the transport sector.

In the current financial and economic situation in the agricultural sector, companies that specialize in growing rapeseed, first use of favorable conditions for the implementation of its export.

There is a necessity of government support of biofuel production on corporate principles to protect against risks during the pilot project and the first years of corporate bioenergy industry in Ukraine.

In the near future, our country has become a leader among the CIS countries, using the experience of European countries to biodiesel and biofuels market competition in Ukraine. So, to establish biodiesel production in Ukraine at this stage there are following priority tasks:

- creation of biodiesel market infrastructure;
- Creation of high-yield, adapted to the conditions of the country's rapeseed hybrids;
- development of modern high-tech cultivation of rapeseed (creation of agro-industrial culture, providing insurance protection for crops, agro technical modernization);
- creating regional zones of concentrated rape growing compliance with the optimization of the structure of sown areas;
- generalization of world experience in deployment and implementation capacity of processing rapeseed oil and to clean synthetic RME (first feasibility study of two options for creating large centralized processing plants and large plants at agricultural enterprises and other stakeholders);
- accumulation of its own experimental experience of types of diesel engines, which should use pure rapeseed oil, synthetic RME and fuel blends with the involvement of commercial diesel fuels of biological components;
- harmonization of national standards with European diesel fuel.

This approach ensures the stability of quality biodiesel in the production process and its use in diesel engines.

In total, whatever it was, but switching to clean fuels economically is dictated by the demands of the present, because Ukraine can not be isolated from these global trends.

Basic definitions and concepts. *Pressing. Output of oil. Soy. Rape. Jatropha. Palm oil. Essential oils. Extraction. Methanol. Catalyst. Reaction. Esther. Transesterification. Biodiesel. Adaptation. Blended fuel. Sunflower. Glycerin. Lecithin. Cetane number. Additives. Erucic acid. Glycerin. Lecithin. Sunflower. Density. Kinematic viscosity. Biofuels third generation. Microalgae. Bioreactors. Strains. Lipids.*

Test questions and tasks

1. Define the concept of biodiesel.
2. Describe the history of biodiesel.
3. What can be the feedstock for biodiesel production?
4. What types of materials has the highest oil output by pressing?
5. Describe the features of production and export capacity of the market of oilseeds in Ukraine.
6. Describe the advantages and disadvantages of the production and consumption of biodiesel.
7. Which countries are world leaders in the production of biodiesel?
8. Describe the dynamics of biodiesel production in the EU.
9. Explain the main biodiesel production technology.
10. What are the features of biodiesel in the cyclical technology using catalysts?
11. What is the range of problems that can occur when using biodiesel as fuel for the car?
12. How does the engine efficiency change by increasing biodiesel additives in diesel fuel?
13. Why whould we add additives when using biodiesel as a motor fuel?
14. Describe the by-products that get in the production of biodiesel.
15. Consider the perspective of production and processing of rapeseed for biodiesel in Ukraine.
16. Describe the block diagram of the construction cost of the plant for the production of biodiesel.
17. What feedstock is used for the production of third generation biofuels?
18. What conditions are most favorable for the cultivation of microalgae?
19. The experience of which countries shows the prospects of biofuel production from algae?
20. Analyze the prospects of biodiesel production in Ukraine.

Fig. 1. Cristanol Plant, Basmarkt, France
Sugar beets are processed into sugar and bioethanol.
Vinasse is exposed to anaerobic fermentation

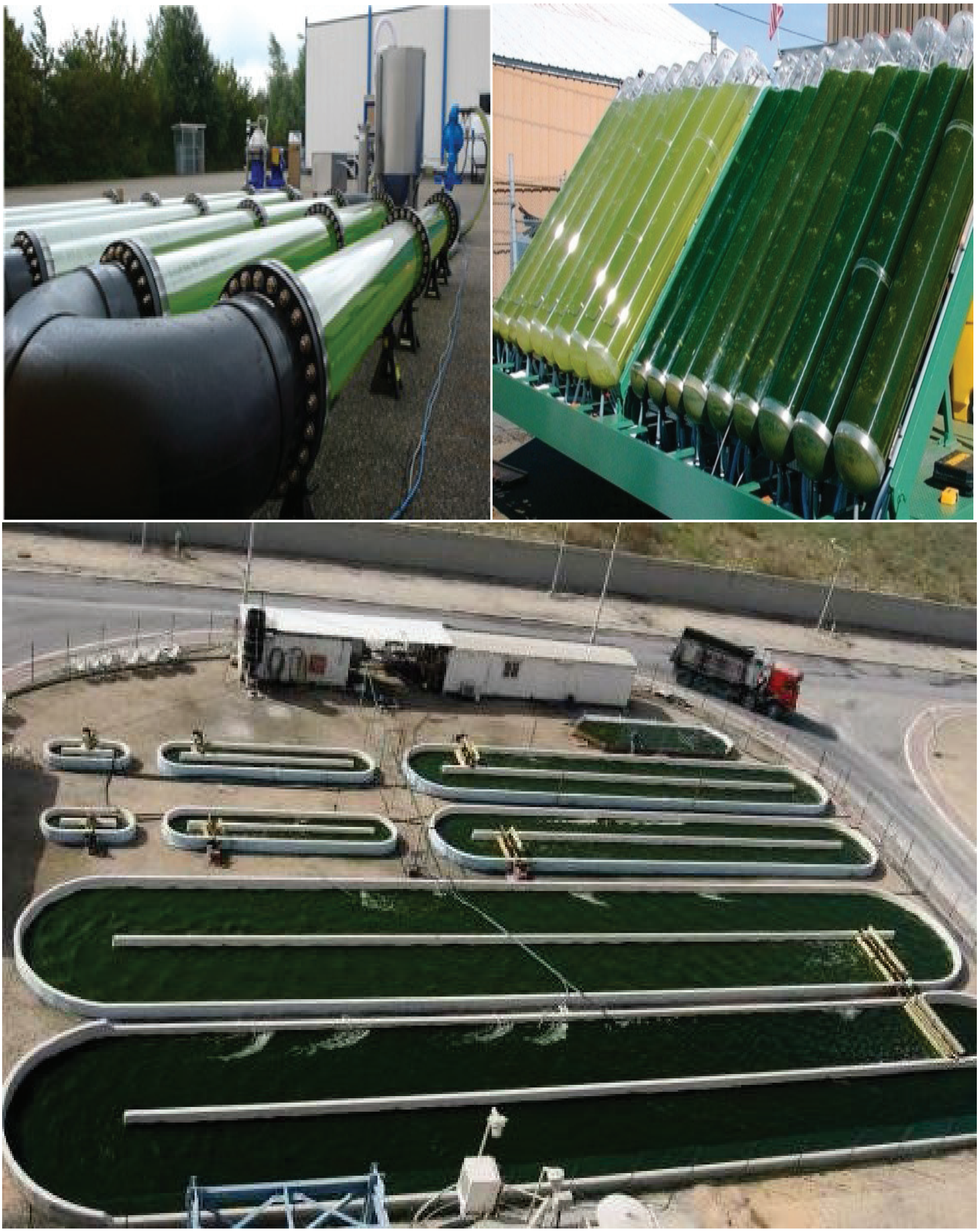
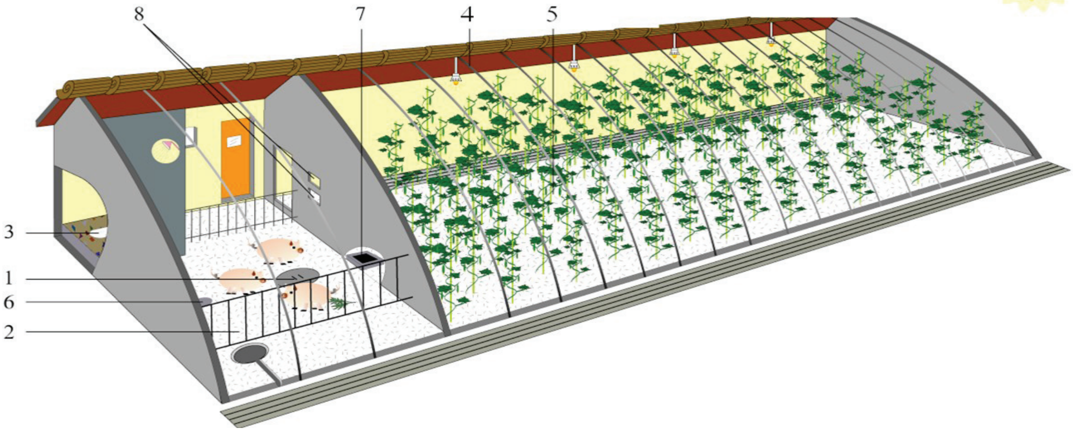


Fig. 2. Bioreactors and open water reservoirs for microalgae growing

Fig. 3. Biogas complex is built on the basis of the Theophilophe sugar plant, Khmelnytskyi region, Ukraine

Fig. 4. Biogas plant construction



1. Biogas reactor.
2. Cowshed.
3. Toilet.
4. Greenhouse.
5. Greenhouse crops.
6. Input reservoir of biogas reactor.
7. Output reservoir of biogas reactor.
8. Ventilation hole.

Fig. 5. The scheme of construction of a domestic biogas plant in Ukraine

Fig. 6. Universal solid fuel boiler, VNAU

Fig. 7. General view of fuel briquettes from biomass

Fig. 8. General view of fuel pellets from biomass

Fig. 9. Heliopark, Ukraine

Fig. 10. Mini-HPP, Cherkasy region, Ukraine

CHAPTER 5
PRODUCTION AND USE OF BIOGAS

Key issues

5.1. General concepts and aspects of biogas production

Biogas is a mixture of gases (mainly methane and carbon dioxide) that is obtainined by biochemical and microbiological methods of processing biological energy resources.

The history of biogas technology reaches far past. Since the 18th century BC, some cases of primitive biogas technologies were reported in China, India and Persia. However, systematic research on biogas production has begun only since 18th century A.D.

The systematic study begun around the same time as modern scientific research and involved many prominent scientists. As early as 1764 Benjamin Franklin described the possibility to light a large surface of a shallow muddy lake in New Jersey. he results of this experiments were reported in a letter to Joseph Priestly in England, who published his own experience with the inflammable air some years later.

The first scientist to describe the formation of inflammable gasses at low temperature in marshes and lake sediments, was Alessandro Volta, who published in Italy the letter "Aria inflammabile native delle Paludi" in Italy in 1776. In 1804, John Dalton gave the correct chemical formula for methane.

The first big scale biogas plant was built in Birmingham, England in 1911 and was used for decontamination of sewage water sediments of the city. Biogas was used for electricity production. Therefore, English scientists pioneered practical implementation of this technology. By the 1920s they have already developed several designs of biogas plants for fermentation of sewage water. The first biogas plant for solid waste fermentation with processing volume of 10 m^3 was developed by Issman and Duselier and built in Algeria in 1938.

During the Second World War real energy deficit experienced by all European countries and Germany and France have put an emphasis on producing biogas from agricultural waste, mainly from manure. As a result, in the middle 1945 in France there were around 2 thousand biogas plans. Naturally, this experience has spread to neighboring countries. Biogas plans were common in Hungary and Soviet solders that have liberated Hungary from German occupation have noted the surprising fact that the manure was not stored in heaps on u ngarian farms, but loaded into closed vessels, from which flammable gas was received.

However, the European biogas plants have lost competition to cheap energy (liquid fuel, natural gas, electricity) during the after war years and were dismantled. A new impulse to development of biogas technologies was received during the oil crisis in 1970 when biogas plants have started to be introduced in south Asian countries. High population density, intensive exploitation of all available soils for growing crops and warm climate necessary for using the simplest biogas plant designs without heating have created a base for intro-ducing several national and international programs on implementing biogas technologies.

The most common are the following types of biogas sets: individual biogas plants, biogas plants for recycling of sewage and industrial waste, large and medium biogas plants. Individual plants have a fairly simple structure. Industrial sets differ from individual with the presence of mechanized processes, heating systems, homogenization, automation.

The EU is a world leader in the field of biogas. Germany is the undisputed market leader in this versatile and forwardlooking industry. Biogas plants made in Germany are in global demand and are preferred because of their superior technology. In Germany the dominant share of biogas is produced by agricultural facilities. Biogas plants in Germany with an installed electrical capacity of 3,352 MW have already replace more than five coal-fired power plants or two large nuclear power plants.

The total amount of biogas plants in Europe is 17,376 (23/01/2017). The number of biogas plants in Europe increased by 3 percent, or 542 plants, in 2015. Significant increases were achieved in some countries, e. g. the U.K. built 77 plants, representing 17 percent of growth; Belgium's growth is by 11 percent, or 20 plants; and the Netherlands built 16 plants, a growth rate of 6 percent.

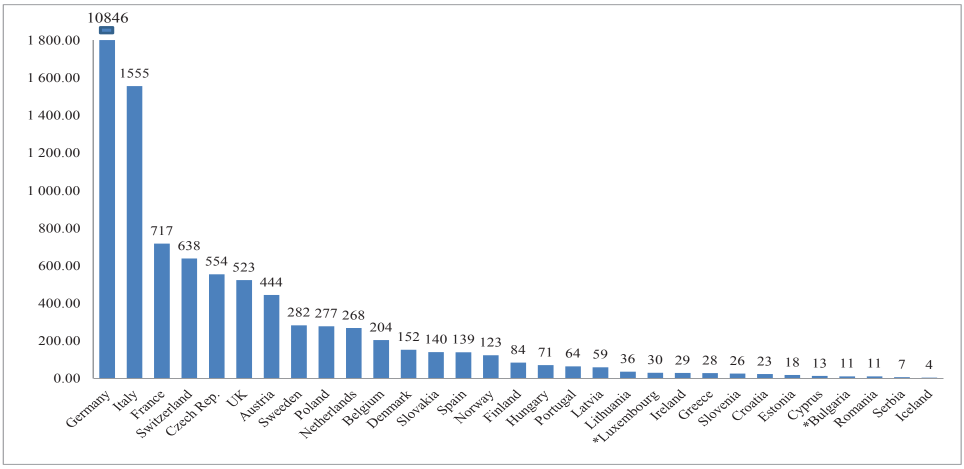


Figure 5.1 The Number of Biogas Plants in Europe, 2015

In the countries with a warm climate (southern provinces of China, India, Ban-gladesh, Indonesia, Nepal, Pakistan) individual biogas plants that recycle or-ganic household waste have become widespread, and the output biogas is used for domestic use (cooking, water heating, lighting).

Biogas is a mixture of gases, and its composition is unstable (tab. 5.1). The content of gases and their number is largely dependent on raw materials used for production as well as biogas technologies. Before using biogas as a fuel, it must be cleaned to remove impurities and some other gases.

Table 5.1

Composition of Biogas

Component	Formula	%
Methane	(CH4)	50-75
Carbon dioxide	(CO2)	25-50
Nitrogen	(N2)	0-10
Hydrogen	(H2)	0-1
Hydrogen sulphide	(H2S)	0-3
Oxygen	(O2)	0-0,1

There are various ways of using biogas. It can be burned at power plants for decentralized block internal electricity and heat or electricity to the central grid; submit a purified and enriched biogas (biomethane) into the gas trans-portation network; use purified biomethane as a fuel for cars.

The power factor in the disposal of animal waste is extremely important: the fermentation of 1 ton of organic matter can produce 350-500 m^3 of biogas with combustion heat 4300-6000 kcal/Nm^3, equivalent to 0.6-0.8 t s.f. Besides, 1 m^3 of biogas generator can produce 2 to 3 kWh of electricity.

Due to its high non explosive properties, biogas can be effectively used in in-ternal combustion engines. Comparative tests showed that the unit costs of diesel fuel were 220 g/kWh at rated power, and biogas – 0,4 cubic meter/kWh.

When we use conventional septic tanks, landfills and lagoons, organic waste often get into groundwater, making sick people and animals, pollute the environment. One of the advantages of biogas plants is that they act as water treatment facilities, reduce chemical and biological contamination of soil, water, air and organic waste processing for high-quality fertilizer. The area of biogas plant is minimal compared to the lagoon areas, which occupy vast areas. This is due to manure storage duration (2-3 years). During this time, in the lagoons, it has been formed organic fertilizer that can be used effectively. This process is much faster in the biogas plant – about one month.

The comprehensive analysis shows that animal waste through the use of mod-ern methods of processing not only solved the problem of energy supply, but also environmental, agrotechnical and socio-economic issues and addressi ng environmental and health objectives should be put first. It is known that animal manure contains a lot of material bacteriological (causative agents of brucellosis, salmonellosis, foot and mouth disease, tuberculosis and other in-fectious diseases) and helminth eggs. Storage and use of unprocessed waste does great damage to the environment, leading to contamination of large ar-eas, poisoning groundwater and water bodies, air pollution and cause serious diseases in humans and animals, which may result in the creation of epide-miological situations.

Furthermore, animals infected with worms increase consume feed by 11% and has a weight gain of 15% compared with the healthy ones.

An animal manure and poultry excrement contains large number of weed seeds, which not only lose their ability to sprout after passing through the digestive tract, but sprout and grow faster being in such a nutrient medium, which reduces the amount of dry fertilizer for crops. In addition, during the anaerobic digestion of nitrogen, phosphorus and potassium moving in a more convenient form for assimilation by plants. The obtaining high-quality fertilizers can greatly reduce the use of fertilizers, pesticides and herbicides, which in turn reduces the production costs of agricultural products. The chemical com-position of manure and effluent almost completely meets the needs of plants in nutrient. It was determined that the replacement of mineral fertilizers on 1 hectare of land need to make about 10 tons of compost. Thus, in terms of farm-ing, the need for processing animal waste is obvious.

Thus, the benefits of production and use of biogas are he followig; obtaining of ecologi-cally clean fuel; reduce dependence on imports of natural gas; the possibil-ity of preventing methane emissions; reduce the environmental impact on the environment by installing biogas plants as treatment facilities on farms, poultry farms, distilleries, sugar mills, meat processing plants; the use of processed manure and other waste bards as high quality organic fertilizer in agriculture.

5.2. Feedstock for Biogas Production

Any bio or organic waste materials that are able to decompose under the action of microorganisms in an oxygen-free environment are suitable for biogas production.

The list of feedstock for biogas production contains the following materials: pig manure; cattle manure; chicken droppings; straw; crop waste; energy crops (corn, barley, sugar beet); fish waste and slaughter plants (blood, fat, intestine); waste of potato processing, production of chips (pills, rotten tubers); waste from juice production (fruit, berry, vegetable, grape pulp); waste from biofuel production (bard, glycerol, molasses); catering waste and spoiled food; sewage; organic waste dumps.

In addition to waste, specially grown energy crops, such as corn silage, silphium and algae can be used for biogas production.

Plant material, mainly cellulose, are also subject to fermentation. The average content of cellulose in straw oatmeal is 36.7%, wheat – 37.2 and rye – 38.3%; stems of corn – 33.7 and 24.0% – in the dry leaves. There are significant opportunities in different component mixtures, which are used as raw material for anaerobic fermentation. Research has also established that a significant increase of methane reached when added to a mixture of swine manure water, biomass, energy crops and 3-6% glycerol.

There are theoretical (physically possible) and implemented technically output of gas. In 50-70-s of the 20th century, technically possible biogas yield was only 20-30% of the theoretical. Modern technologies allow to increase the biogas output from 60 to 95% on a regular installation.

To calculate biogas yield of a certain type of material, it is necessary to determine the fat, protein and carbohydrates compound. It is necessary to calculate the percentage of substances that easily decompose (fructose, sugar, sucrose, starch), and substances that decompose slowly (eg cellulose, hemicellulose, lignin). After determining the content of substances biogas yield for each substance can be calculated separately and then added. Output of biogas from different raw materials are presented in Table. 5.2. and 5.3.

Table 5.2

Biogas Output from Animal Waste

Raw material	Biogas output, m3/t of the substrate	Methane output of 1 ton of dry matter m3
Cattle Manure	25	210
Swine manure	28	250
Bird excrement	140	280

Biogas Output from Biomass Plants

Raw material	Biogas output, m3/t of the substrate	Methane output of 1 ton of dry matter m3
Corn silage	200	340
Grass silage	180	310
Sugar beet	130	350

Biogas Output from Farm Waste

Raw material	biogas Output, m3/t of the substrate
Molasses	166
Glycerin	421
Green waste facilities	43
Fruit and grape pomace draft	49
Food waste	57

Table 5.3

Biogas Output From Sugar Beets

Leaves of sugar beets, t		75 – 180, m3
Silage leaves of sugar beet, t		200 – 400, m3
Pulp from sugar beets	Humidity 88%	75 – 90, m3
	Humidity 76%	150 – 180, m3

Table. 5.4 shows the annual rate of gas consumption by one person and the number of animals or birds that provide similar biogas yield.

Table. 5.4

The Number of Animals or Birds, Providing the Production of Biogas at a Rate of Consumption per Person

Purpose of biogas	Annual rate of gas consumption per person		The number of animals or birds providing biogas output at a rate of consumption per person		
	Mkal	tons of standard fuel	Cattle	Pigs	Chickens
Cooking	640	0,116	1,5	6	15
Cooking and heating water (cooker, water heater)	800	0,182	2	9	23

However, it should be noted that from 40 to 60% of biogas in the anaerobic fermentation is spent on biological equipment needs, and to maintain the process temperature in digesters. In this regard, extremely important is the search for more rational design solutions of digesters that allow to increase significantly the yield of biogas from the same amount of organic waste.

Farm animal waste is waste of organic origin – mostly manure and manure runoff of cattle, pigs and chicken manure. Accompanying materials can be used for bedding – straw, grass, turf.

In terms of energy obtaining, efficient use of animal waste can be get from stalled keeping of cattle.

On average, humidity of feces of cattle and pigs is 80-85%, chicken manure – 75%. The presence of pus padding reduces humidity to 70-78%, flushing water increases humidity. Runoff of manure with humidity over 96% recycle wasted by anaerobic fermentation, so obtaining biogas from biomass livestock manure on water-wash method should be abandoned.

We know that because of the environmental, agronomic and economic factors creating powerful livestock facilities is impractical. Optimal situation for pigs farm is 24 000 of heads. Table. 5.5 shows specifications of manure and chicken manure processing in the bioenergy equipment for optimum quantity of livestock and poultry farms.

Table 5.5

Characteristics of Animal Waste Processing

Indicator	Pig farm (24,000 heads)	Cattle farm (1,000 heads)	Poultry farm (500,000 heads)
The daily output of the manure at 90% humidity and output of excrement at 70% humidity	144	85	100
Characteristics of biogas: daily output, thousand of m3; methane content, %; commodity biogas, thousand of m^3; Annual output of commodity biogas, ths of m^3;	6.0 65-70 3.0 1100	2.2 55-60 4.0 400	10.0 65 5.0 1800
Commodity production of energy for the year: Electricity, million kWh heat, Gcal	1.8 1548	0.67 576	3.0 2580
Annual output of fertilizers, mln tons	2.8	1.2	5.0

Biogas production is most efficient at fermenting waste of animals such as manure water or manure. This raw material can be mixed with other economic waste. Depending on the feedstock, biogas output can be at different levels and energy values. Number of generated waste depends on the age and type of animals and the season. The average amount of biogas, which can be obtained from 1 m^3 of organic animal waste, is estimated at 20-25 m^3, although profitable level is about 30-35 m^3.

This amount of biogas can be obtained by combining animal waste and economic waste with another substance, witch is characterized by high content of dry organic matter such as waste of food industry or plant mass. According to available data, addition of 10% of corn silage at specific humidity (30%) to manure water (W = 85%) increases biogas production by 50-60%, and 5% additive of glycerol waste (W = 70%) increases the amount of produced biogas by 60-70%.

Adding fat and municipal sewage from nearby farms can increase significantly the biogas output per unit volume of material.

Loaded feedstock is divided into three main categories: agricultural – manure water, manure (taking into account the greater hydration only as supplementary material), energy crops, residues and other biomass; industrial – starch, slaughterhouse waste, milk, sugar refineries, pharmaceutical, cosmetics and paper industry, etc; business – organic waste, municipal waste water, garden trimming and more.

Animals diet, their age and other factors identified in the pilot study of fermentation processes affect on the output of biogas from animal waste.

Fermentation material can also be divided into primary (fermentation which can occur alone, without the addition of other materials) and auxiliary.

The main fermentation material is manure, manure water, purulent fluid, young grass and auxiliary – vegetable waste from vegetables, organic waste, leftover food, fats, molasses, organic products decompose naturally by biological, economic drains and so on.

Mixed fermentation, i.e. simultaneous fermentation of various materials, prolongs the process retention (storage) and requires a large volume digesters, but this measure is bought up by increasing biogas production.

However, too large load of organic substances can disrupt biobalans and eventually lead to a sudden decrease in biogas production and even the death of colonies of bacteria responsible for the fermentation process.

During the mixed fermentation with a high content of organic matter, it may appear an issue on a significant reduction in the value of pH, leading to the inhibition process. Compared with the fermentation of homogeneous material, maintenance installations for mixed fermentation require more attention, as there may be unusual phenomena such as foaming in the reactor. This phenomenon can be prevented if you increase the intensity of mixing biomass in the chamber or reduce loading of additional materials.

The dosage fermentation material should be homogeneous, and composition of additional components requires professional approach. Previous manual preparation of waste provides separation of hazardous materials and maintaining the necessary level of homogeneity of the loaded material.

The high degree of risk associated with servicing systems for mixed fermentation caused by the fact that each component of the mixture has different physical and chemical properties and the process requires individual approach.

5.3. The Technology of Biogas Production on an Industrial Scale

Before the construction of industrial installations of fermentation, we have to investigate experimentally and determine the relevant parameters and modes of the system (method of mixing, control the formation of foam and sediment) and process management (volume of downloading additional materials, exposure time etc.).

There are six types of biomass fermentation which are taking place simultaneously or sequentially: ammonium, nitric, nitrogen releasing oxidation, acid, methane.

Industrial plants differ from individual in mechanical systems, heating, homogenization, automation. The most common industrial method for the production of biogas – anaerobic fermentation in digesters.

The biogas plant is a complex of processing equipment and facilities designed to produce biogas and organic fertilizer by anaerobic digestion of plant biomass and animal origin. The composition of the biogas plant usually in-cludes storage tank of prior preparation and substrate fermenter, tank-fermented mass storage block and power plant.

Industrial biogas plant consists of the following elements (Fig. 5.2): homogenization capacity (mixing), bootloader of solid (liquid) materials, fermentation reactor, mixers, gasholder, the water supply system and heating, gas system, pumping station, separator, the control devices, block of automation.

Fermenter (bioreactor) can be positioned vertically or horizontally. Most often it is made of steel or concrete. Thermal insulation is an indispensable part of the reactor, thus it can isolate both outside and inside. Standard insulation materials can be used for insulation. Powerful biogas plants should be heated. The substrate is heated typically created via the circulation of hot water or heat exchanger.

Because of insufficient duration of the fermentation process, material in the reactor can not be fully fermented. Therefore, the increased output of biogas between the reactor and the final repository are sometimes called to refermented tank.

First coenzymes are placed inro pre-preparation process and homogenized (milled). Homogenization occurs most often in the tank with powerful stir-

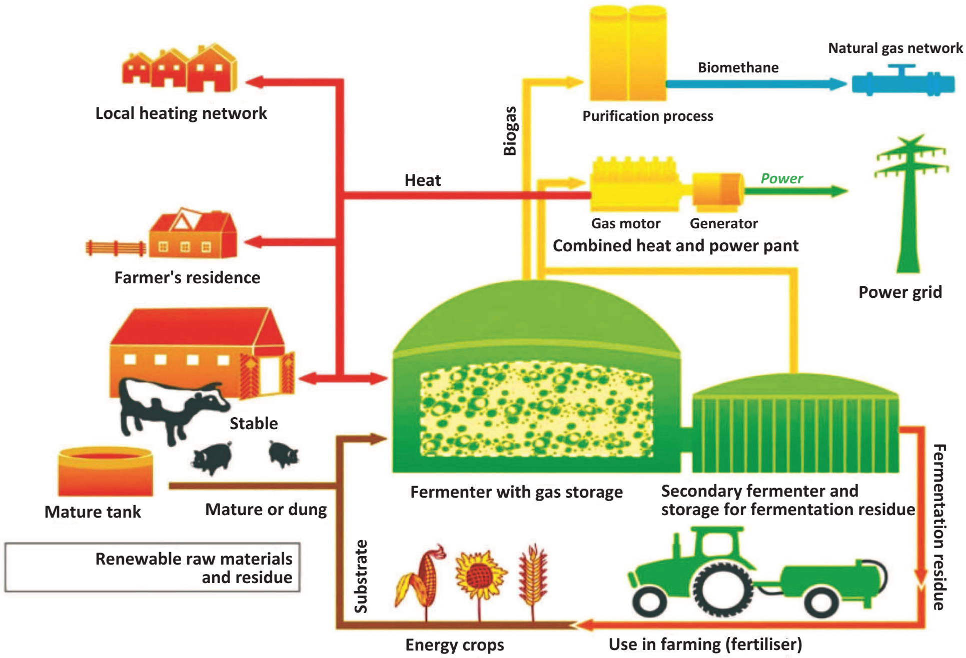


Figure 5.2. Industrial Biogas Plant

rers at 70°C for one hour. The reactor is gastight, fully sealed tank made of reinforced concrete. This construction is an insulated because the inside of the tank should be with fixed temperature for microorganisms.

The process of fermentation is influenced by such factors: temperature; humidity environment; the level of pH; the surface area of the particles of feedstock; frequency of substrate supply; presence of substances that slow down the fermentation process; stimulating additives.

Microorganisms play an essential role in the process of fermentation. To ensure a methane fermentation, it requires the presence of methanogenic microorganisms matter – Bacillus perfringens. These organisms develop only in favorable conditions – in an anaerobic environment by slightly alkaline reaction at 6-70°C. To improve the fermentation, it is necessary to graft appropriate colonies of bacteria. It would also encourage start fermentation by adding the already fermented substrate that cultivate raw appropriate bacteria strain. In order to standardize the temperature of organic matter under fermentation and undergoes and proliferation of microorganisms in the biomass, it has been systematically mixed. Mixing of fermented substance prevents local fermentation caused by pathogens.

As the process is the result of bacteria, they need to create the appropriate conditions: an appropriate temperature to the strain of bacteria; exposure time, determining the time of inflow of feedstock to the biogas reactor (it should be made in the way to prevent leaching bacteria with capacity); appropriate portion of downloading additional materials (too much leads to overloading of the system and too little – to the fading reaction); the content of inhibitors of the process – such as antibiotics or pesticides.

In the reactor, there are beneficial bacteria that feed on biomass. Methane decomposition of biomass is influenced by three types of bacteria in three stages. In the supply chain these bacteria feed on the life of previous products. The first type – bacteria hydrolysis, the second – acid-producing, third – methane-producing. The waste product of methane-producing bacteria is biogas.

In the first phase, anaerobic digestion occurs schedule macromolecular compounds (carbohydrates, fats, proteins) to low molecular weight of organic compounds. At the second stage, by involving acid-producing bacteria there is their further expansion with the formation of organic acids and their salts and alcohols, CO_2 and H_2, and then H_2S and NH. Final bacterial conversion of organic matter to carbon dioxide (CO_2) and methane (CH_4) is at the third stage (Fig. 5.3).

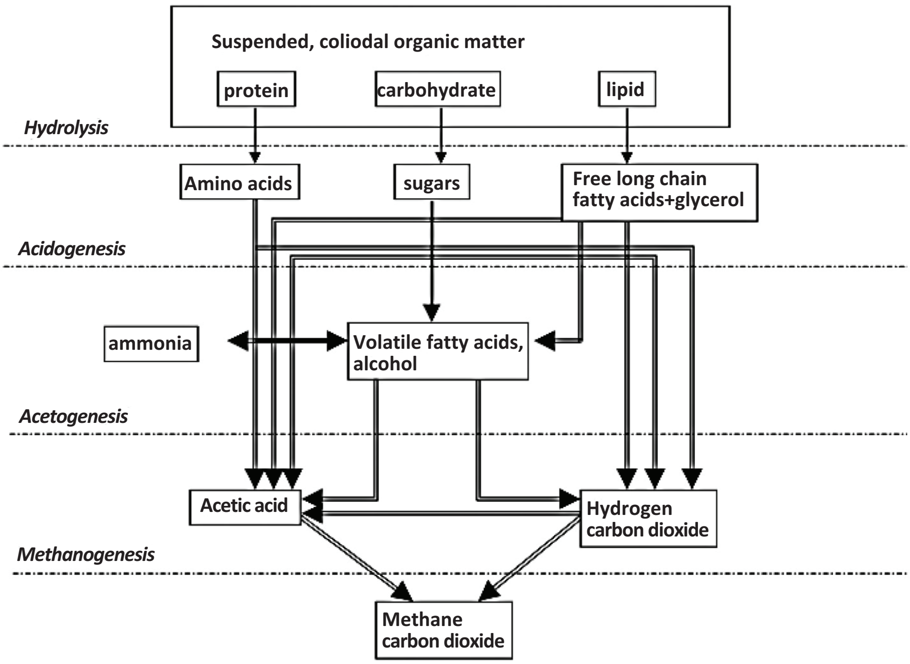


Figure 5.3. Methane Formation Scheme

These reactions occur simultaneously, and methane-producing bacteria are more sensitive to environmental conditions than acid-producing. The rate and extent of fermentation anaerobic methane-producing bacteria depend on their metabolic activity.

Methane from a substance that undergoes fermentation takes place only under anaerobic conditions, when there is no air access. Therefore, we have to use special fermentation tanks, closed fermentation chamber and other similar equipment.

A very important factor in effective motion fermentation process is temperature of fermented mass. Methane fermentation begins at 6°C. At a lower temperature, methane discharge stops. Along with increasing temperature, there is rapidly increased allocation of gas. So at 30°C biogas discharge occurs in 12 times faster than at 10°C.

Fermentation in biogas reactors can occur at mesophilic and thermophilic conditions. When using mesophilic bacteria, reasonable temperature conditions are from 30 to 38°C, thermophilic bacteria – 55-60°C. Thermophilic bacteria are more productive than mesophilic. They over exposure time (12-14 days) mineralize as much organic matter as mesophilic bacteria for 21-36 days. This allows to low fermentation capacity of tanks. Also thermophilic regime has advantages in terms of ecology, because this mode completely destroyed almost all the pathogens. But thermophilic mode requires additional energy to support the required reaction temperature. In addition, the quality of organic manure is worse than mesophilic.

Mesophilic regime imposes less stringent requirements for accuracy of temperature maintenance, but not always fit in terms of climate.

To sustain bacteria vital activity and effective run of the fermentation process it requires a constant supply of substrate, heating and periodically stirring. Stirring is carried out mechanically established through the reactor stirrer or hydraulically (pressure produced by pumps or gas).

There are such mechanical mixers as motofork, paddle and propeller. The operator must be sure that there is no appearance of floating layers of sediment. In addition, microorganisms should be provided with all necessary nutrients. Fresh mass should be fed into the reactor in small portions several times a day. The average duration of hydraulic sedimentation within the reactor (depending on the substrates) is 20-40 days. During this time, organic substances inside the mass are metabolized (transformed by microorganisms).

During the using of bioreactors, it is necessary to monitor the pH level constantly, the optimum level of which is within the range of 6.7-7.6. Regulation of this indicator is carried out by adding a solution of lime.

In modern biogas production, three main technologies of methane fermentation are used: continuous, variable and periodic.

The fermentation is constant or with the short interruptions in supply of raw materials (organic waste, animal secretions, etc.) to the reactor. An outflow of fermented mass is going on simultaneously with the supply of fresh manure. Raw materials of fermentation must have a liquid or semi-liquid consistence. The best for this is the feres of cattle or pigs. This technology requires the smallest fermentation chambers and realizes the process of continuous production of biogas. Fermentation tanks can be installed horizon-tally or vertically, various methods can be used for mixing the mass (mechani-cal stirrer, pumping raw materials, blowing biogas, etc.), as well as methods of input and output of raw materials. Technology with continuous fermentation refers to the most technically advanced.

Variable fermentation requires the construction of less than two fermentation tanks, filled alternately with raw materials. After some time (from eight weeks to several months), the first tank is loaded, leaving a small amount of sludge for inoculating bacteria at the next batch. The production of biogas using this technology is cyclical. The more tanks, the shorter the intervals between gas production cycles from different capacities.

Periodic fermentation occurs like a fermentation-variable process, but using a single fermentation tank that is periodically filled and, after the end of the fermentation, is released. This technology is used with dense feedstock, such as manure. The fermentation tank is also the composition of manure, which is released when exporting the fermented waste to the field. There are some period requirements of keeping manure keep in the fermentation tank – not less than 6 months.

With such requirements and such technology, gas production is possible only twice a year with the lowest volume in comparison with other technologies.

The results achieved in the development of rural technical support on using biogas plants are just a small step towards the solution of the overall complex problem. Technologies for the processing of animal waste using biomass of plant origin in biogas plants are being spread in connection with the reduction in the number of cattle and the rise in the cost of traditional energy carriers.

However, the technical support in Ukraine of these technologies does not meet modern requirements and needs appropriate development. An important condition for the development of biogas technologies at the current stage is to increase the efficiency of technical means for biogas production with the minimum possible emissions of harmful gases into the environment.

The concept of technical and technological solution of the problem of joint use of organic fertilizers and plant biomass in biogas reactors is developed and implemented. The process begins in the primary tank, where liquid and solid organic fertilizers are mixed to a homogeneous mass and fed to the reactor using a pump. If the mixture is sufficiently liquid, then the primary tank can be discarded by feeding the feed directly to the reactor. This becomes possible with the use of a mixture of fodder beets. Fermentation takes place in a reactor in which a constant maintained temperature of 35-45°C. According to this temperature regime, the bacteria work efficiently. From the reactor, the mixture flows into a storage, where fermentation is completed. This is how the technological process of the work of the biogas plant is carried out in a shelter-flow type.

During the fermentation in the reactor, a fresh mixture is added constantly to the fermentation mixture, and displaces the processed mixture into another container. With the help of mechanical mixers, the fermentation process in the reactor is distributed evenly throughout the volume. The fermentation mixture remains in the reactor for as long as it is biologically necessary for the decomposition of organic substances by bacteria.

Under optimal conditions and 35-45°C temperature in the reactor, organic substances are decomposed by 90-95% in 35-45 days. Special attention should be paid to the homogeneity of the fermentation mixture. In a reactor, bacteria must be constantly provided with organic substances. This requires a constant supply of a homogeneous organic mixture to the reactor.

To ferment some types of raw materials, there is a need in special two-stage technology. For example, *poultry* manure, alcohol vessel are not processed into biogas in a conventional reactor. To process such feedstock, an additional hy-drolysis reactor is needed, which allows to control the level of acidity, so that bacteria do not perish because of the high content of acids or alkalis. It is pos-sible to process these same substrates using a one-stage technology, but with co-fermentation (mixing) with other types of feedstock, for example with ma-nure or silage.

Biogas has a small amount of sulfur in its composition, which affects the longevity of biogas plant units. To extract sulfur from biogas, fresh air is blown into the reactor surface by means of a small compressor to the surface of the fermentation mixture.

This leads to the fact that special microorganisms convert gaseous sulfur into a solid state, which becomes a valuable component of organic fertilizers.

Biogas coming from the reactor, almost has 10% saturated with water vapor and mainly has a high content of hydrogen sulphide, causes corrosion of pipelines. Primary cleaning of biogas from water occurs during its cooling to the level of ambient temperature in the gas tank and the pipeline.

The obtained biogas is accumulated in special tanks (gas tanks), which balances fluctuations in the quality and volume of biogas and ensures its uniform supply to the heat and power module for further conversion to electricity.

The transferred waste is stored in special tanks. Their volume should be planned so that the fermented substrate can be stored during the non-vegetative period, when organic fertilizers are introduced into the fields. Typically, these tanks are covered with a hard coating or film cap to avoid loss of nitrogen.

The key to the economic success of biogas production is the correct choice of parameters and dimensions of the plant in combination with the optimal choice of substrates as well as in achieving high indicators of the use of the block-electric and electric power plants, and the capacity for generating electricity while simultaneously utilizing the generated heat. The qualification of the enterprise and its employees are also important. The possibility of imple-menting the wasted substrate plays an important role in the economic effi-ciency of the biogas plant. Besides, it is an effective and ecological replacement of expensive mineral fertilizers.

5.4. Production and Use of Biogas by the EU Countries

Now in Europe, three concepts of biogas production are the most common namely:

– production of equipment for farming;

– powerful lines for processing manure designed to meet the common needs of several farms;

– powerful enterprises specializing in the processing of organic wastes of various origins.

Favorable state policy in the field of alternative energy has led to the fact that Germany remains the unconditional leader in biogas production of in the EU for more than 20 years.

The construction of biogas plants in Germany began in 1999. By integrated program on climate and energy (IEC), the German Federal Government predicted the development of biogas production in 6 billion cubic meters by 2020. Thanks to the 2000 Law “On Renewable Energy Sources” and its two additions adopted in 2004 and 2008, the Government received the basis to stimulate the broad development of production and use of renewable energy sources. This Law regulates the purchase and payment of electricity received exclusively from renewable energy sources, in accordance with the established rates of payment. Paid for the use of renewable raw materials bonuses have caused considerable interest in the production of biogas based on energy plants and other organic materials obtained as a result of the agricultural use of natural resources. As a result, a large number of new biogas plants were created.

The number of biogas plants operating in Germany in 2013 exceeded 8,000. The biogas obtained from them is used for the operation of block heat power plants with electric power from 25 kW to 1.0 MW and thermal power from 50 kW to 2.0 MW. In 2013 the total electrical capacity of these units was 3000 MW. At the same TEED capacity of 1 MW is sufficient to provide electricity to several villages or a processing plant. Most biogas plants in Germany are connected to the state power grid. Excess electricity is sold to power supply companies at an increased “green” tariff established as a direct rule of law.

Biogas in Germany is mainly obtained by fermenting energy crops mixed with manure. The main energy crop used is corn silage. Organic industrial waste and food waste are also used for biogas production.

The country is dominated by small biogas plants operating in the power range of 250 kW of electric power with an average fermenter volume of 3000 m^3. Among installations dominate structures with vertically located reactor systems. In 70% of cases, multistage technological process is fulfilled at the plants, and most often in the mesophilic temperature regime. The time of hydraulic settling of the substrate in the whole system is from 29 to 289 days, and in the multistage plants it is determined the dependence of the settling time on the content of organic dry matter in the substrate mixture. The higher the content of organic dry matter in the substrate, the longer the settling time. Single-stage systems operate at significantly lower settling times – mostly at less than 100 days.

The demand for biogas plants in electricity for their work is on average 7.9% of the electricity produced. With respect to the substrate being loaded, there is an unambiguous relationship between the specific electricity demand for the domestic needs and the amount of liquid manure in the substrate mixture. The higher the proportion of liquid manuris, the lower the amount of electricity consumption per ton of loaded substratis.

According to the number of biogas plants in operation, Sweden ranks second among the EU countries. The total amount of biogas production in the country exceeds 4500 thousand m^3 per year, which made it possible to organize a network of gas stations and transfer about 3000 cars to biomethane. In Sweden, biogas was started to be produced at municipal wastewater treatment plants in the 1960’s. The main incentive was the desire to reduce and disinfect the volume of sewage. Nevertheless, the oil crisis of the 1970’s changed the attitude towards the development of biogas technologies and the construction of new plants and made them a priority. Thus, as a result of the active build-up of the construction of new biogas reactors and plants the dependence on imported oil and gas supplies was simultaneously reduced, and the problem of municipal waste disposal was solved.

The construction of biogas plants in the country is supported by significant subsidies from the state in accordance with the policy of supporting the development of renewable energy sources and sustainable development projects. This support is about 30% of the total cost of the project.

By 2020, Sweden plans are to become independent from the import of oil and gas and completely switch to various types of biofuels and alternative energy sources.

It is important to note that incentive tariffs for electricity derived from biogas and other renewable sources have been introduced in all EU countries.

Construction of biogas plants, in addition to positive environmental and economic effects, provides jobs and gives the opportunity to receive heat and electricity from local feedstock, without burdening the state with their needs. This is much more effective and more expedient than buying natural gas from other countries.

By setting up biogas production, food industry enterprises are able to fully or partially supply themselves with heat and energy by recycling waste products. Cities can fully or partially transfer municipal transport to biogas, obtained by fermenting sewage. Any landfill can be retrofitted with the necessary equipment and become a source of heat and electricity.

5.5. China's Experience in the Construction of Individual Biogas Digesters

China is one of the world's leading countries in investments in renewable energy sources. Fast growth of investments in the field of renewable energy sources was the result of its study of the experience of industrialization of the Western countries. The Chinese government has begun to actively pursue a course aimed at developing technologies with low levels of greenhouse gas emissions, which has important influence on country's further development.

The State Committee for Development and Reforms of China announced "Renewable Energy Development Program" on March 18, 2008, according to which by 2020 the share of renewable energy sources in the total volume of energy consumption should reach 10%. The annual consumption of regenerative energy sources in the country is 300 million tons of fuel equivalent.

In 1920, the first homogenized biogas plant was built. In 1920, the active introduction of small biogas plants began in 1980, thanks to the existing state program, which was aimed at the gasification of rural areas (Figure 5.4). Now in China, there are more than 40 million similar biogas plants of a household type, which produce about 12 billion cubic meters of biogas a year. It is expected that by 2020 80 million small biogas plants will work there. Domestic production of biogas is controlled by 18 standards, including national and 12 industrial ones, among which there are standards for materials for the construction of biogas plants, construction regulations, verification and suitability for use, standards for biogas plates and auxiliary equipment.

China is one of the few countries in the world with a specialized research institute that is engaged in scientific development in the field of biogas technology development (Chengdu city, Sichuan province). The Institute has a training center for training specialists from Europe, Asia and the Pacific.

The process of biogas plant building with a volume of 6 to 10 m^3 takes four days. The structural materials are brick or concrete and cement. When the installation is complete, fresh manure and fermentation sludge can be loaded into the reactor.

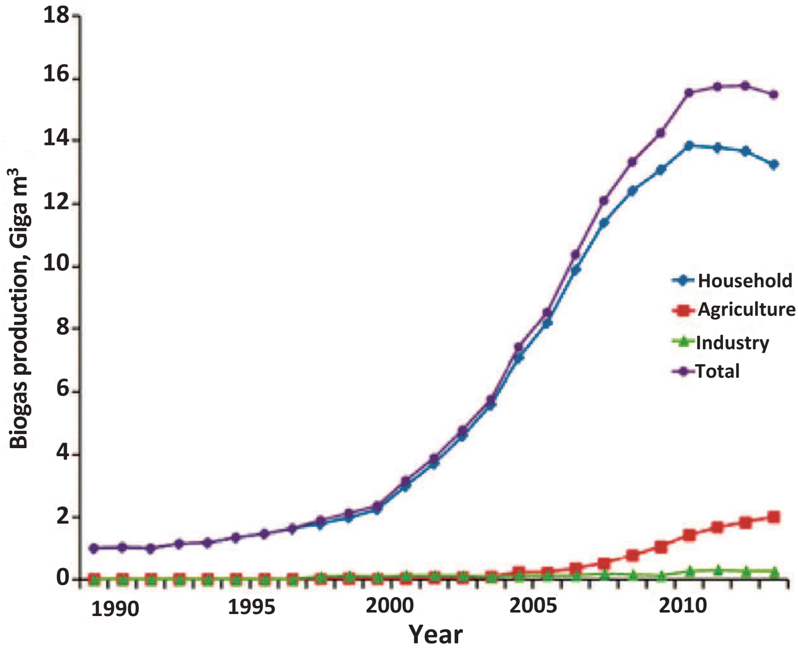


Figure 5.4. China Biogas Production in Different Sectors from 1989 to 2014

The feedstock for biogas can be pig or cow dung, rabbit or chicken droppings and toilet waste. Depending on the composition of the processed raw materials, it is possible to expect the release of biogas of different levels and energy values. The amount of generated waste depends on the age and type of animals that are bred as well as on the time of the year. The biogas production is higher in summer, since the temperature is much higher.

In order to start the fermentation process, a small amount of fermentation material from the operating reactor must be added to the reactor. After that the process of biogas formation will begin in a week.

In a biogas plant with a volume of 10 m^3, 1/8 part of the volume is used for fermentation raw materials. The biogas plant consists of three main elements: the inlet tank, the outlet tank and the fermentation reactor. At the top, the reactor is closed by a movable cover into which a biogas pipe is mounted. The outer cover is installed movable, since once a year the biogas reactor must be completely cleaned to avoid the accumulation of solid particles on its bottom.

Fresh manure is fed into the reactor under the influence of gravity, and the transferred pipe is pushed out of the reactor due to the design features provided, the inlet pipe is located below the exit pipe (Figure 5.5).

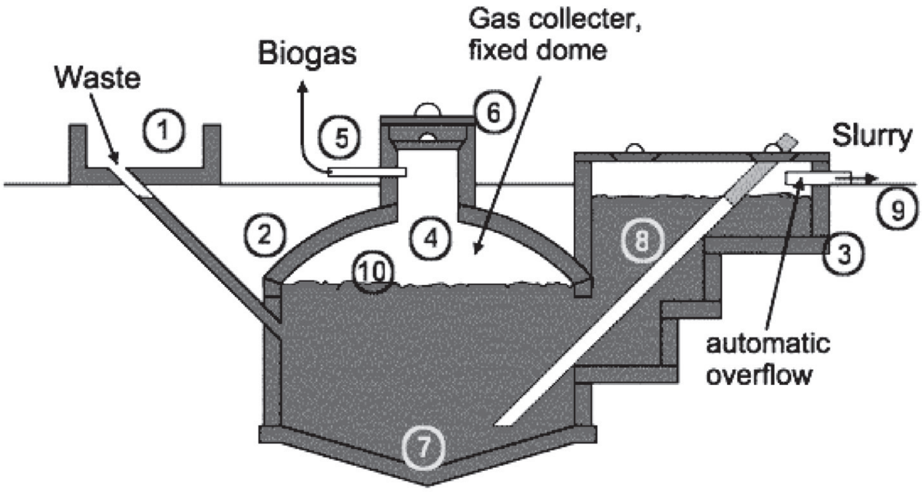


Figure 5.5. Structure of an Anaerobic Biogas Plant of a Home Type

Mixing of fermented raw materials will also occur. The gas formed during fermentation will rise upwards and accumulate under the dome of the reactor. Daily biogas plant can produce about 2 m^3 of biogas at the temperature of 30-35°C. For the life of bacteria and biogas, formation, the temperature should not be lower than 10°C. To ensure the production of 2 m^3 of biogas in the reactor, manure from 3 cows or 9 pigs is needed daily (Table 5.6). Besides, the fermentation of raw material can be combined.

Table 5.6

Calculation of Biogas Production Potential on the Basis of Content of Dry Substances (VS)

Animal waste	Number of vs per head, kg/24hous	Degree of fermentation VS, units	Biogas output per 1 kg of VS, m^3/24 hours	Biogas total output, 1000 m^3/24 hours
Cattle	5	0.35	0.4	0.7
Pigs	0.7	0.4	0.8	0.224
Poultry	0.036	0.45	0.9	0.14

Fermentation occurs in anaerobic biogas reactors, i.e. without air. This digester produce gas that is enough for daily cooking three times a day for a family consisting of 3-4 persons. The obtained biogas is fed through a special tube into the kitchen. Pressure measuremnt and desulfurizer are set with biogas reactors to purify biogas from sulfur contaminants. After cleaning, biogas can be upgraded to natural gas standard and used by people. The heating power of the obtained biogas is 15 MJ/m^3.

The production costs of individual biogas plants are about 3000 UAH and service life is 20-25 years. Payback period of money invested in the construction is two years. In addition to biogas, a positive factor is improving environmental conditions by waste using. Fermented mass looks the same as raw materials, with humidity close to it. However, this high-quality ready disinfected and devoid of odor organic fertilizer is suitable for direct introduction into the soil.

In the waste products of animals and humans, there are different forms of bacteria and viruses. Pumping of effluent into the environment leads to pollution of soil and water, as well as distribution of various diseases, infection with worms, chicken pox, measles, avian influenza, salmonellosis, hepatitis, polio, yellow fever and many others.

Instead, fermented mass has destroyed pathogens, worms and ability of wild grass seeds to germinate, but it has been saved the nutritional value of manure for nitrogen, phosphorus, potassium and others. Due to the neutral value of pH, fermented mass used as fertilizer prevents leaching and acidification of soils. With sustainable use of biofertelizers, yield of crops is increased by 30-50%.

Another advantage of biogas is that normal mineralization of manure is about 40%, and minerals are bound to organic and therefore less absorbed by the plants. Instead, mineralization of fermented mass is 60%, and minerals transer into a form available to plants.

Thus, the use of individual biogas plants allows largely to solve the problem of recycling organic waste, provide preconditions for effective cultivation of environmentally friendly products and receive thermal energy for farm use.

5.6. Prospects of Biogas Production in Ukraine

Natural gas is used by humans in many aspects: while burning, it releases a lot of heat and little harmful substances (in comparison with coal and petroleum products), it can be used not only for the needs of industry and heating, but also for generating electricity and as a motor fuel. However, its advantages are leveled due to limited reserves on the territory of Ukraine and a rapid increase in value. The price of imported natural gas is increasingly incompatible with the economic benefits of its use.

Ukraine has consumed gas which comes through pipelines with the length of thousands of kilometers. Although it is possible to obtain alternative biogas from any organic waste without any deficit. THe production of biogas is a real example of industrial ecology with the generated energy from the waste of economic ac-tivity, and as a by-product, biogas producers receive valuable organic fertilizer.

Now a large number of villages in Ukraine have not natural gas. Accord-ing to the data of NAFTOGAZ of Ukraine, the gasification level with natural gas is 78.1% in cities and 38.2% in rural areas. In total, according to the State Statistics Service of Ukraine, on January 1, 2014, in the country there were 885 localities and 28471 settlements. THe number of gasified villages with only natural gas only is 2774 settlements, or 9.7% of the total number. In addition, the annual cost of natural gas consumption is constantly increasing (Figure 5.6).

According to this trend, the use of this energy resource is gradually reduced. In the last years, the agro-industrial complex of natural gas and electricity consumption has decreased by 9%. Natural gas belongs to non-renewable sources of energy and annually has a tendency only to increase its value. There is no doubt that by the middle of the XXI century natural gas will become a rare and very expensive fuel. In addition, Ukraine does not have enough of its own natural gas reserves and is directly dependent on importers, who set higher gas

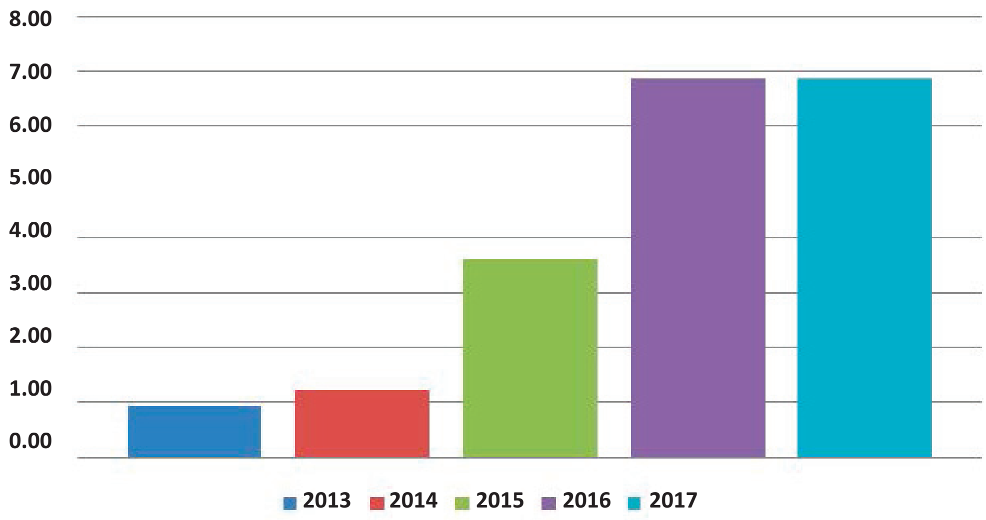


Figure 5.6. Prices of Gas for Households

prices year after year. In addition, gas pipelines are exposedto corrosion in spite of their protection.

The cost of setting 1 km of the gas pipeline in rural areas with a pipe diameter of 50 mm is 60-70 thousand UAH. In settlements, there is a pipe with a diameter of 90-110 mm, the cost of its setting is 115-150 thousand UAH. Thus, the cost of gasification of a house is on average from 5 to 10 thousand UAH.

One of the effective ways to supplement and replace traditional fuel and energy resources, especially in rural areas, is the production and use of biogas, which is formed as a result of the use of methane digestion technologies for the waste biomass and livestock biomass.

Animal waste and other organic wastes are environmental pollutants that can be used to benefit. The construction of individual biogas plants should become the state program of Ukraine. The population that install biogas plants will not only receive environmentally friendly and free biogas, but will also get rid of the problems of utilization of livestock waste, the development of diseases and pests and receive highly effective organic fertilizers.

To achieve a high level of biogas production in the process of anaerobic fermentation, it is necessary to adapt the biogas plant in the climatic conditions of Ukraine. In winter, air temperature in our country reaches low indicators. Forming biogas bacteria cease to exist at a temperature of 10°C, and when the temperature falls below 7°C, they die completely. To prevent this, it is possible to build biogas reactors under the barn, where cattle are kept. In such case, the biogas reactor should be heated in winter in a natural way without additional energy input.

It is also possible to cover the biogas reactor with hay or other heat-damaging materials. In addition, by slightly changing the design of the biogas plant, it is possible to use a certain part of the obtained biogas for heating the reactor. However, with a small size of the biogas plant, the last method is not cost effec-tive, since it is more appropriate to use biogas formed exclusively for in domestic needs. Therefore, in cold winter conditions, natural methods of heating the reactor are preferred.

The production of biogas in Ukraine can be ensured not only by the fermenta-tion of organic waste, but also through the methane fermentation of biomass. Now in Germany, there are about 2 thousand large biogas plants producing biogas from corn silage. Compared to other energy crops, corn silage has advantages due to low costs of growing and storing. In addition, the production of biogas from corn silage is marked by a reduction in greenhouse gas emissions and high fuel economy. Besides maize can be stored on the field for up to one year with low losses in dry mass. In recent years, agrarian companes of Ukraine. Hat the average yield of silage maize of 350-360 c/ha. Thus, to day nearly 2 million hectares of agricultural lands are occupied by corn, the grain from which is exported. So we can produce up to 26 billion cubic meters of biogas in Ukraine (Table 5.7), and therefore solve the problem not only of the dependence on natural gas imports, but also provide additional jobs and ensure incomes to the state budget.

Table 5.7

Potential for Biogas Production From Corn Silage in Ukraine, 2016

Indicator	Value
Production of corn, mln t	63.0
Exports of corn, mln t	39.5
Yields of corn t/ha	5,9
Area share for export, thousand ha	8,965,873
Harvest of corn silage, kg/ha	350
Potential corn crop that can be used for biogas production, mln t	313.7
Output of biogas m^3/ton of corn silage	250
Potential of biogas production, million m^3	78,443

The cost of corn for silo in 2016 was 228 UAH/t. Since the output of biogas from 1 ton of silage is about 250 m^3, the cost of 1000 m^3 of biogas made from corn silage will not exceed $40.

Large-scale production of biogas can be a factor that will help to overcome the energy deficit, improve the environmental situation, provide new jobs and develop the state's economy.

In Ukraine, large-scale pig and poultry enterprises annually generate more than 3 million tons of organic waste (in dry matter), processing of which will allow to receive about 1 million tons of fuel equivalent in the form of biogas, which is equivalent to about 8 billion kWh of electricity. At the same time, in Ukraine, there are about 2 million non-gasified rural estates. The experience of countries that are not provided with natural gas convinces that it is expedient to gasify remote rural areas with small bioenergy plants working on organic waste from rural estates. The introduction of 2 million units in Ukraine will allow to receive about 2500 mln m^3 of biogas per year, which is equivalent to 13 billion kWh of electricity and can provide house hold in rural areas with 10 million tons of organic fertilizer per year. The expediency of obtaining in Ukraine biogas from organic waste, such as the manure and droppings, is caused by their quantity and concentration both in the individual farms and in the regions.

To ensure village household demand for the electric and thermal power, it is necessary to produce 10 billion cubic meters of biogas a year. This amount can be obtained from crop and livestock waste, waste from dairies, meat processing plants and other processing enterprises as well as through the use of biomass of special "energy" crops. In addition, the introduction of bioenergy technologies will contribute both to the improvement of the ecological state and to the creation of about 400 thousand new jobs in Ukraine, a radical acceleration of intensification and an increase in the profitability of agriculture.

Additional funds for the implementation of energy-efficient te chnologies can be attracted when Ukrainian enterprises use the joint implementation mechanism under the Kyoto Protocol to limit greenhouse gas emissions to the atmosphere. However, mass production and use of biogas in Ukraine did not start because of the lack of appropriate state policy, and, consequently, the lack of sufficient explanatory information for agricultural producers (potentially the most interested in its use), lack of orders for the industry, no doubt capable of producing low-cost domestic equipment.

With the replacement of natural gas and liquid petroleum products by biomass, the funds are curently spent on their imports from Russia and Turkmenistan, remain in the regions (including payments to farmers and foresters for the supply of biomass) and are spent on their development and development of the country as a whole, and do not to support the economies of neighboring countries.

Basic definitions and concepts. *Biogas. Methane. Carbon dioxide. Biogas plant. Anaerobic fermentation. Homogenization. Hydrolysis. Acidogenesis. Methanogenesis. Mesophilic. Thermophilic. Methentenk. Fermentation reactor. Alkaline medium. Gasholder. Separation. Biofertilizers. Substrate. Bacteria. Strain. Pathogens. Mineralization. Gas generators. Treatment facilities. Organic fertilizers.*

Test questions and tasks

1. Give a definition of the «biogas» concept. Describe the history of the development of biogas technologies.
2. Give general trends in the production and use of biogas.
3. Name the main types of plants used for biogas production.
4. What is the raw material for biogas production?
5. What gases does biogas consist of?
6. What determines the release of gas from fermented raw materials?
7. What are the features of modern technologies for obtaining biogas?
8. Describe the temperature regimes of methane fermentation.
9. What are the main methane fermentation technologies?
10. What kinds of bacteria are involved in the process of anaerobic digestion?
11. What are the elements of an industrial biogas plant?
12. Describe the principle of operation of an industrial biogas plant.
13. How can we use the transferred organic waste?
14. Describe the production of biogas in the EU countries.
15. What countries have widespread individual biogas plants?
16. What are the specific features of the construction of individual biogas plants in China?
17. Describe the main advantages of individual biogas plants.
18. What are the main directions of development of biogas production in Ukraine?
19. Analyze the potential of biogas production from corn for silage in Ukraine.
20. What are the advantages of biogas production and use in Ukraine?

CHAPTER 6
BIOFUELS: ECONOMIC, ENERGY AND ECOLOGICAL SECURITY OF THE STATE

Key issues

6.1. Science-Based crop Rotation for Effective Biomass Production

The most urgent issues of the present day in the sphere of ensuring national security in general and in the economic sphere in particular are a significant increase in financial security and a maximum improvement in the investment climate; achieving a real growth of economy and the formation of an effective system of social protection of the population; strengthening the labor safety, increasing the level of the state food security; providion of reliable guarantees of man-made, ecological and technological safety, development of scientific and technical potential; strengthening of energy security; ensuring information security of the state; deepening of integration relations; increase the level of competitiveness of the state taking into account national interests in all components of foreign economic policy.

The material basis for this process should be the revival and accelerated development of promising sectors of the national economy with the availability of constructive programs for restructuring the country's economic complex.

The main task of the state in the context of ensuring economic security is the creation of an economic, political and legal environment and institutional infrastructure that would stimulate the most viable enterprises, investment processes, and the production of promising competitive goods.

The agrarian sector of the Ukrainian economy is the main lever that already provides and will continue to provide economic development of the state, performing a multifunctional role. Despite this, the state should pay attention to agriculture, its sustainable development of production on a scientific basis, which can ensure food, energy and environmental security, conservation of natural ecosystems and landscapes.

In order to make agriculture more effective we have to use crop rotation. As we know, crop rotation is the practice of growing a series of dissimilar or different types of crops in the same area in sequenced seasons. It is done so that the soil of farms is not used for only one set of nutrients. It helps in reducing soil erosion and increases soil fertility and crop yield. The list of crops or their groups is called a crop rotation scheme. Necessity of crop rotation is caused by a number of factors. In the twentieth century, summarizing the experience of practical agriculture and the achievement of agronomical science, D.M. Pryanishnikov defined four types of crop rotation, namely – chemical, physical, biological and economic.

The chemical basis for crop rotation is the effect of the proper rotation on the conditions of plant nutrition. Agricultural plants carry out a different number of elements from the soil with a yield, so a prolonged one-stage cultivation or growing similar in absorption of certain elements of crops leads to unilateral depletion of the soil to certain elements and, as a result, to a decrease in yield. For example, after sunflower, which leaches a lot of potassium during harvestting, it is impossible to plant potatoes, which also requires a lot of potassium. Chemical bases also include such phenomena as the enrichment of soil with nitrogen by leguminous plants, the transfer of hard-to-reach forms of phosphates into those available for leguminous and buckwheat. Crop rotation also prevent changes in soil pH.

Physical causes are the effect of crop rotation on the structure, physical properties and moisture of the soil. For example, perennial grasses improve the structure and physical properties of the soil, tilled ones – to a lesser extent, and even vice versa. The soil of alfalfa, sugar beet, corn is drying up the soil.

Biological fundamentals of crop rotation. Alternating crops reduce the possibility of overburdening of crops, disease and vermin damage. For example, the long-term growth of oats in one place leads to its strong clogging of wild oats, winter wheat – to rust contamination, potato – to phytophthora, nematode, etc.

The reasons for the alternation are the scientific justification of the structure of the croping areas, which are developed in accordance with the need to grow certain crops, natural conditions (climate, soil, terrain) and biological characteristics of plants. Different crops respond a unequally to their growing. According to the respond to the rotation (alternation), they can be divided into: weakly motivated, moderate-sensitive, strongly-typed, and incompatible.

Weakly sensitive (conditionally compatible) crosp are corn, millet, hemp, buckwheat, potatoes (in the absence of nematodes). These crops can be re-grown or for several years grown in one field without significantly reducing their yield.

Mid-sensitive crops include peas, sugar beet, wheat, barley, oats, rye, vetch. Crops negatively respond even to repeated crops and are marked by significant crop yields under proper crop rotation.

Strongly sensitive – crops are lupine, flax, sunflower, cabbage, clover, alfalfa. They re-respond strongly to rotated crops. High productivity of self-incompatible crops is ensured only by proper crop rotation taking into account the permissible periodicity of the crops in the same field.

Incompatible crops are those that are unreasonable or impossible to place one after the second in crop rotation be cause of their biological features, presence of common diseases and pests. For example, it is impractical consistent cultivation of various legumes, wheat after barley, oats – after barley, and vice versa, beet – after rape and oats and the like.

The types of crop rotation are determined after the use of:

– field crops (mainly cultivated field crops and industrial crops, which account for more than 50% of the total area in these crop rotations);

– fodder crops (mainly forage crops are grown, such rotations include farming and grassland crop rotation);

– special crops (they grow mainly certain specific crops, which are not advisable to be grown in the field crop rotations – vegetable, rice, flax, and soil protection).

According to the presence of the leading crops in crop rotations, their types are determined. For example, according to growing mainly cereals and tilled crops such crop rotation is called grain and row crop rotation. Also there are grain-fallow, grain-fallow-potato, row and other crop rotation.

According to the number of crop rotation fields, there are a *10*-year rotation, 9-year rotation, 8-year rotation, etc.

The introduction and development of crop rotation includes a number of successive stages, such as the introduction of crop rotation alternatives and a rotational table for crop rotation, the development of a system for processing and fertilizing soil, and the preparation and implementation of a plan for the transition to the introduced crop rotation.

The plan for the transition to crop rotation should look like a number of requirements: to take into account the correctness of the crop rotation; do not cause a decrease in the number of products; leading crops must be sown after the best precedin crops; if necessary, weed from fields should be divided into pairs in one field to sow one crop, which is important for the use of machinery and preparation of the field for inclusion in a new crop rotation; the transition period should last no more than 2-3 years.

The transition period is considered complete, and the crop rotation is mastered when all crops are sown after the preceding crops that are planned for the scheme of the introduced crop rotation.

Farms maintain documentation on crop rotations. All information about the crop rotation is recorded in the "Field History Book". This book, or a register of crops, includes information on a common part throughout the crop rotation and for each field separately. A crop rotation scheme, transition period table, soil treatment and fertilization system are recorded in the general part.

In the sixth chapter of the book, which is assigned to each field, its number is fixed (it is unchanged during the whole period of the crop rotation), information about the crop, yield and all the works in chronological order (the time and type of processing and fertilization of the soil, the sowing period and sead quality, watering, introduction of chemical agents of plant protection, harvesting terms, etc.) are registered.

Thus, taking into account scientifically grounded crop rotations, it is possible to achieve a jeld in crease of a particular crop, but also to prevent soil depletion. But all these measures for the introduction of crop rotations should be carried out and strictly controlled at the state level to prevent barbaric processing and depletion of soils. It should be noted that in some "purposeful" media sometimes there are reports that some crops, which are used as biomass for biofuels production of biofuels, in particular – rape, substantially deplete the soil.

Most of the leading scientists and agrarians after a thorough study of this issue confirm that when applying scientifically grounded crop rotations, soil fertility is not violated, and vice versa: sowing rape and after its harvesting, winter wheat yield increases by a quarter.

In order to effectively grow bio-feedstock for biofueles production in modern agriculture, one of diverse variants of schemes of scientifically grounded crop rotations has been developed and proposed (Table 6.1).

Table 6.1

Scheme of Scientifically Justified Crop Rotations for Growing Biocontractable Materials

Sequence number	1	2	3	4	5	6	7	8	9	10
1	Fallow	Sun-flower	Winter barley	Soy-bean, Peas	Winter rape	Winter wheat	Barley	Sugar beat	Winter wheat	Corn
2	Corn	Fallow	Sun-flower	Winter barley	Soy-bean, Peas	Winter rape	Winter wheat	Barley	Sugar beat	Winter wheat
3	Winter wheat	Corn	Fallow	Sun-flower	Winter barley	Soy-bean, Peas	Winter rape	Winter wheat	Barley	Sugar beat
4	Sugar beat	Winter wheat	Corn	Fallow	Sun-flower	Winter barley	Soy-bean, Peas	Winter rape	Winter wheat	Barley
5	Barley	Sugar beat	Winter wheat	Corn	Fallow	Sun-flower	Winter barley	Soy-bean, Peas	Winter rape	Winter wheat
6	Winter wheat	Barley	Sugar beat	Winter wheat	Corn	Fallow	Sun-flower	Winter barley	Soy-bean, Peas	Winter rape
7	Winter rape	Winter wheat	Barley	Sugar beat	Winter wheat	Corn	Fallow	Sun-flower	Winter barley	Soy-bean, Peas
8	Soy-bean, Peas	Winter rape	Winter wheat	Barley	Sugar beat	Winter wheat	Corn	Fallow	Sun-flower	Winter barley
9	Winter barley	Soy-bean, Peas	Winter rape	Winter wheat	Barley	Sugar beat	Winter wheat	Corn	Fallow	Sun-flower
10	Sun-flower	Winter barley	Soy-bean, Peas	Winter rape	Winter wheat	Barley	Sugar beat	Winter wheat	Corn	Sun-flower

The use of certain types of agricultural products that are used in public nutrition for biofuel production is an urgent problem that is manipulated by opponents of the introduction of renewable energy sources to ensure the country's energy security, especially oil traders – in order not to let the competitor develop, who do not want to have competitors in the market and share the profits, as well as the vast majority of foreign advisers, who would like to see Ukraine as a feedstock appendage and a supplier of cheap biomass.

It is proved that 20 million hectares of land are needed, to ensure the necessary level of food security of Ukraine and its energy security at the expense of production of its own energy carriers of biological origin, and we need only 10 million hectares in order to produce the required amount of bio feedstock for biofuel production.

It should be noted that in the case of bio-feedstock material production in accordance with scientifically grounded crop rotations, the economy of the country from the processing of energy-saturated crops to biofuels will receive a significant amount of related products, whose feed in the feeding of animals will be supplemented by a significant amount of food.

Calculations show that with achieved average annual yield in the country's agroindustrial complex and the application of crop rotations, 7.0 million tons of bioethanol, 9.7 million tons of biodiesel and 12,700,000 tons of soybean and rapeseed meal, 8.54 mln tons of residue from sugar beet processing and 11.45 t of vinasse can be produced (tab. 6.2).

There is no doubt that it is much more profitable to trade finished products than raw materials. The correctness of this can be traced, unfortunately, to the example of grain trade, which is successfully exported by grain traders from Ukraine. From such trade in the first place, most lose their producers, who buy grain at very low prices. But at the same time, our state is also losing, because together with grain, grain traders take out jobs, food, budget revenues, and wages of citizens of Ukraine that could potentially be employed in processing technologies for this raw material.

So, for example, in 2016, more than 39 million tons of grain were exported from Ukraine. Taking into account the average annual export from Ukraine of 22 million tons of feed grain, from which it would be possible to get 5 million tons of bioethanol.

When processing the specified amount of grain for bioethanol, there are more than 8.8 million tons of vinasse, which can be used as for animal feeding. This volume of vinasse can produce almost 3 million tons of meat in addition to the state's food reserves.

Table 6.2

Calculation of Biofuels Output from Energy Crops by Using Crop Rotation

Name of crops	Estimated harvested area, mln ha	Yield, t/ha	Total yield, mln t	Biofuel output, l/t	Total volume of biofuel, mln l/mln t	Accompanying products, %/mln t
Rape	1.38	2.1	2.9	420	1218/9.02	40/0.94
Soybean	0.52	1.5	0.78	120	945/0.7	40/0.31
Corn	2.0	4.7	9.4	420	3942/2.78	40/3.76
Wheat	3.8	3.8	14.44	360	5200/3.60	40/5.78
Barley	1.5	3.03	4.55	360	1640/1.15	40/1.82
Rye	0.1	2.3	0.23	360	85/0.06	40/0.09
Sugar beat	0.3	35.6	10.68	100	103/0.73	80/8.54
Other crops	0.4					
Total: 10,0 mln ha Outputs: bioethanol – 8.3 mln t, biodiesel – 1.6 mln t, solvent cake – 12.7 mln t, vinasse – 11.45 mln t, residue – 8.54 mln t 1 t of bioethanol = 1418 l 1 t of biodiesel = 1350 l						

Using 1.5 mln t of bioethanol on the domestic market cause savings from the oil purchase about $4 billion. 2 million tons of bioethanol for export can give 1.5 billon dollars' incomes.

As we known, scientists of Ukraine have developed modern technologies for bio-fuel production from biomass. Confirmation of these calculations is a number of scientific studies of leading Ukrainian scientists and practitioners.

The refore, we can make the following conclusions:

1. Ukraine has a huge biomass potential as feedstock for biofuel production based on the effective application of scientifically based crop rotations.
2. Domestic scientists have developed and equipped modern technologies for:
   - growing of energy-containing bio feedstock;
   - production of equipment;
   - processing of biomass into biofuel.
3. Ukraine has already yot facilities for the production (bioethanol and biodiesel fuel).
4. Production, consumption and export of biofuel in Ukraine:
   - reduce Ukraine's energy dependence on the energy imports;
   - reduce environmental pollution, especially from the automobile gas emissions;

- increase the production of foodstuffs, and fortify food security of the state;

5. Stabilize the activities of the agro-industrial complex and enable to start tillage of the lands that have not been cultivated (radioactively contaminated as a result of the Chernobyl disaster), and have been underused due to insufficient and unreasonable price for petroleum fuel.

6. Provide additional jobs, especially in the agricultural sector. Especially it refers to the cultivation and processing of sugar beet and other crops, which volumes have sharply fallen in Ukraine.

7. Replacement of 30% of gasoline and diesel fuel with bioethanol and biodiesel, and it is just 9% of Ukrain's acreages, which is practically the lands that are not cultivated and overgrown with weeds due to the lack of sufficient oil products and investments.

6.2. Production of Biofuels in the Context of Ensuring Food Security of the State

In the 21st century humankind deals with three inter-connected challenges, namely *food* security, climate change, and *energy security.*

The solution to these problems has met certain contradictions since biofuel production has been started. At the same time, food is a dominant resource, because:

1) it is an indispensable energy resource for the functioning of the human body;

2) substitutes for traditional energy carriers can be obtained from food products, and the reverse process has not been invented yet;

3) biofuel producing is possible only at a certain level of providing people with food resources;

4) there are high growth rates of food consumers in the world (according to the data of FAO): in 2000, the population was 6 billion people, in 2017, it reached 7.5 billion. Further growth of the planet's population can significantly limit the availability of food, water and even oxygen. This has already affected, because in 2009 the number of hungry people in the world reached a record high and amounted to 1.023 million people.

Nowadays and in the nearest feature, Ukraine will be involved in the cycle of biofuel production as a producer of raw materials, or a producer, consumer and exporter of biofuels. In order to choose the right position for the country, it is necessary to carry out a thorough economic expertise of this process constantly and promptly.

With the allocation of a part of agricultural raw materials to biofuel production, the provision of food security of the state becomes critically important.

Food security is the protection of the vital interests of people, which is manifested in the provision by the state of unhindered economic access of people to foodstuffs in order to maintain their livelihoods.

What does the level of food security of Ukraine mean?

1. Daily and annual amount of food sufficient to ensure the normal functioning of the human body and preserve its health. It is provided by a variety, balance and caloric intake, which is 3200 kcal/day. The norms were developed by the Ministries of Labor, Economics, Finance, and the Federation of Independent Trade Unions of Ukraine in October, 1991.

2. This is the number of necessary food products intended for 45 million people in the country.

In total, the area of arable land suitable for growing crops in Ukraine is 32.5 mln ha. Data of Table 6.3 shows that there is a need for 16.4 million hectares to meet the consumer needs of all residents of Ukraine .

According to calculations, Ukraine has a powerful potential for growing biomass suitable for energy use without threatening the country's food security, because the production of agricultural products in Ukraine covers the domestic demand, and at the same time agricultural products are also exported a lot.

Table 6.3

Calculation of the Arable Land Area to Meet the Consumer Needs of the Population of Ukraine (Estimated 45 Million People)

Products	Kg/year (by resolution)	Kg/year (according to calculations)	For 45 million people (mln t)	Area (mln ha)
Meat, meat products	49.5	60	3	6.6
Milk and milk products	232.94	250	12.5	3.5
Animal oil	5.94	6	0.3	1
Eggs	254.19	260	13 ·109	0.4
Fish, fish products	15.88	20	1	0.2
Potatoes	89.83	100	5	0.362
Vegetables and melons	106.09	110	5.5	0.35
Fruits and berries	67.55	70	3.5	0.35
Bread and grain products	93.52	100	5	2
Oil and margarine	7.4	10	0.5	0.725
Sugar and confectionery products	28.14	30	1.5	0.5
Other food products	10	10	0.5	0.4
Population – 45 mln				16.4 mln ha

If we want to answer the question "Is it advisable to use food feedstock for processing into fuel?" it is necessary to come back to the times when all agricultural work in the village was provided by draft animals. From the outset of agricultural development farmers used 30% of their crop for feeding animals, plowing, sowing, transportation, threshing, and construction workers.

Thus, Ukraine, studies show that the problem of "food versus fuel" is not urgent because:

1. The country both provides itself with sufficient food products, while using mainly extensive methods of agricultural production and incomplete use of land resources and exports a part of agricultural commodities.
2. The country has a significant natural, economic, scientific and production potential to increase the volume of agricultural production by improving the culture of farming, development of innovative technologies and, on this basis, by increasing the yield of agricultural crops.

In recent years, the main reasons for the decline in the yield of crops, including energy crops and the deterioration of its quality is the violation of crop rotations, the main components of the technology of crops growing. The results of scientific research and long-term production activity of farms have proved that the crop rotation is the unshakable foundation and guarantee of the stability of farming, because they positively influence all important soil conditions, primarily nutrient (including humus and microbiological), water as well as air and thermal, contribute the active detoxifying harmful substances, thus determining the entire complex multifaceted development conditions of agrobiocenosis complex, with green plants as the major component.

The scientific principles of crop rotation include the proper selection of the preceding crops and the optimal combination of single-species crops, while observing the permissible periodicity of their return to the same field. In this arrangement, the maximum rotation performs basic biological function – phytosanitary and avoids excessive use of crop protection chemicals.

Analysis of statistical data for recent years indicates that many production structures violate the established requirements for crop ro-tations or even allow permanent crops. This is prompted by the conjuncture of the market of agricultural products, determines the production, first of all, the cultivation of profitable crops. However, it is indisputable that the development of agriculture in Ukraine as a whole should be based on the introduction of a rational system of crop rotation – field, forage and special.

Leading biofuel production countries cultivate bioresources from specialized crops systemically. This is due to the fact that the recoupment of capital costs for the construction of processing plants and the purchase of appropriate means for processing bio-feedstock for fuel directly depends on the sustainable supply of bio feedstock. Bio-feedstock in the form of energy crops (oil, sugar and starch-containing), according to literature sources and ex-perience, are a reliable part of the solution of the problem of the biofuel market development in the countries of the world.

To assess the possibility of reorienting the use of the part of agricultural land intended-for food production to growing crops as bio-feedstock for the production of biofuels, without the reduction of the level of food production, we have applied the approach used by the State Statistical Service of Ukraine and its calculations.

Thus, we can non-cultivated lands in different ways. In the form of raw materials, take the niche of a cheap feedstock appendage on the world markets while buying gasoline, diesel fuel, gas, oil at monopolistically high prices. And it is possible in several years to replace an insufficient part of petroleum products with biofuels of domestic production, reorient oil and gas of domestic production to the chemical industry, use biofuel waste, which is a grain bard and high-protein pulp for additional extraction of 1.5-2 million tons of meat or 15-17 million tons of milk.

With the minimum norms of consumption in Ukraine, it is necessary to produce about 720 kg of grain per capita, according to rational standards – 970 kg, or 34 and 46 million tons, respectively, taken into account the costs of live-stock. The potential possibilities of grain production in our country are 70-80 million tons.

So, in these conditions, Ukraine can completely solve not only the problem of food security on the main types of products, but also food independence and have significant surplus products. At the same time, the strategic direction of using products (grain for example) depending on the world market situation should be as follows:

– complete provision of the domestic needs in food products;

– the rest is used for the production of bioethanol and exported in the form of livestock products or bioethanol and only then – in the form of grain.

The agricultural and energy markets are interrelated: agriculture requires a lot of energy; oil is included in the transport component, it is used in the production of fertilizers, pesticides, components for machinery, etc. That is, expensive material and technical resources have somewhat inhibited the build-up of production and influenced the formation of prices for the benefit of their growth. But there is also an indirect dependence. The rise in prices for oil and its derivatives has prompted more active use of alternative energy sources. In the late 90-ies of the 20th century, this led to the formation of the bioethanol market. Taking into account the significant volumes of processing of grain resources, it is possible to assert fundamentally new changes in agriculture: now, in addition to the traditional food direction, its functions expand to the energy component. This increases demand and is one of the factors of the current imbalance between production and consumption.

On the other hand, the constant growth of the population in the world on average by 1.2% per year attracts attention. In addition, in the most populated India and China (the total number of their population is 37% of the world), in recent years there has been observed a significant growth in the economy. Thanks to this, millions of people improved their well-being and overcome poverty, which, of course, is a positive indicator. But the rapid increase in income also changes the diet in favor of a larger intake of animal proteins. So, according to the FAO, the annual consumption of dairy products per person in China in 1969-1971 was at the level of 2.2 kg/person, in 1995-1997 – 8 kg/person, and in 2001-2003 this figure increased to 13.5 kg/person. In India, the consumption of dairy products doubled, if you compare the data of 2001-2003 and 1969-1971, there is a simi-lar situation with meat consumption: in China, during 2001-2003, compared with 1969-1971 it increased in 6 times and reached the level of 53 kg. Such global changes in the consumption of livestock products, of course, require an adequate response from the production side. This, in turn, exerts additional pressure on demand of cereals in the world indirectly, through the replacement of cultivated areas of pastures, and directly to fodder for livestock.

Summing up all the above factors, it can be stated that the demand for grain crops will increase. In the long term, it can be assumed that demand is stabilizing, producers will be able to reach a new level of production, which should contribute to the final formation of the bioethanol market.

Moreover, the cultivation of energy crops for biofuel production is very profitable and will be able to improve the complex economic situation in the Ukrainian agro-industrial complex, and bring commodity producers to a new level of production and sells.

Considering the plans to increase the production of biodiesel in the EU, we can expect that the production of rapeseed in Ukraine and its exports will grow.

Now the calculations on the diversification of the export of grain and oilseeds indicate a more effective option of using the export potential in comparison with the existing one.

Ukrainian grain traders export 15-20 million tons of grain forage annually, as well as an average of 1.6 mln tons of oilseeds (sunflower, rapeseed, soybeans, etc.) and almost 4.5 mln tons of finished oil (or 85 percent of the harvested crop).

It is known that practically all fodder grain and part of oilseeds (in particular rapeseed and soybean) exported from Ukraine are processed abroad for bioethanol and biodiesel.

It would be more effective for the state economy to establish biofuel production and consumption. This would give an opportunity to produce from 3 to 5 million tons of bioethanol, refusing to import oil and gasoline. All volume of vinasse would remain for feeding, and this is 1-1.5 mln tons of meat weight gain.

6.3. Energy Balance as a Criterion for Estimating the Production of Bioethanol and Biodiesel from Grain and Oilseeds

Due to the limited availability of its own traditional energy sources, an increase in the volume of agricultural production is possible with the introduction of energy and resource-saving technologies, unconventional and constantly renewable energy sources.

The share of fodders in the structure of costs for the production of livestock products is 50-80%. Any of their kind is the cumulative source of energy obtained through direct photosynthesis. The effect of its transformation into the energy of livestock products becomes the criterion for assessing the energy-saving balance. Therefore, along with the criterion of economic evaluation of any technological process in agricultural production, the criterion for estimating the energy balance should be taken into account.

Energy balance is the ratio of the energy received by using fuel to the energy that was spent to produce it.

In the mid-1970s, the energy balance of bioethanol and biodiesel was sometimes negative. However, since then, there has been a jump in the development of technologies for obtaining them. Now the energy balance of bioethanol production varies from 1.3 (from corn) to 3.6 (from cellulose raw materials), and the energy balance of biodiesel production is from 1 to 3.5.

The rapid increase in the use of energy resources can be explained by the increase in output and considered as a progressive phenomenon: the demand for industrial and agricultural products is growing very rapidly, and increasing its output is impossible without additional provision of the industry with appropriate energy resources.

According to the published results of various studies, agricultural production output increase requires an increase in energy consumption, half of which is liquid fuel. To increase such production in 2-3 times, its energy intensity grows in 10-15 times. Especially high energy intensity belongs to industrial livestock complexes and farms.

For example, crop yields increasing requires output increase and improving the quality of fertilizers, expanding irrigated areas, increasing the capacity of agricultural processing enterprises, etc.

The corn, sunflower and rape yield increase is based on the introduction of new varieties of these crops and technologies for their cultivation with a reduction in the energy intensity of the technological process. Energy estimation of energy costs in the structure of its total costs in the technological process of growing maize for grain with an optimum yield of 50 centners/ha shows that energy consumption for soil cultivation is 10%, fertilizer applying – 53%, pesticides – 12%, sowing – 5%.

The cost of harvesting, transporting and drying grain is 20%. In general, energy costs reach 25,000 MJ. Considering the volatility of energy prices, the cost of aggregate energy has been increased to 30,000 MJ. With the 65% starch content in corn, its gross yield from 5 tons of standard moisture yield will be 3.25 t/ha. 667 liters of alcohol with 1 s. t. of starch can give 2168 liters of bio-ethanol, or 57,700 MJ of energy.

Thus, the charges of aggregate energy when growing maize for grain at a yield of 50 c/ha are completely compensated by the renewable energy contained in bioethanol when it is produced from such quantity of grain. At the same time, the revenue energy will be 27,700 MJ.

Increasing the yield of corn grain to 70 c/ha provides the production of renewable energy increase in the form of bioethanol in 1.5 times. It can be used for other energy needs in the economic complex. At the same time, the production of 5 tons of corn grain to bioethanol can give almost 2 tons of post-alcohol production waste in the form of DDGS. This distillers grain has the same protein content as high-protein feed and meet zootechnical requirements with taking into account the feeding characteristics of farm animals.

The data on nutritional value of DDGS obtained from corn grain are given in Table. 6.4.

Table 6.4

The Chemical Composition of DDGS Derived from Corn Grain
(Average, % in Absolutely Dry Matter)

Sample Name	Raw protein	Raw fat	Raw cellulose	Raw ash	Non-toxic extractive substances
DDGS from corn grain	32.35	5.97	10.52	1.86	49.30
Corn grain	9.38	4.31	1.61	1.36	83.34

Two tons of DDGS from corn grain provides 5 tons of milk, which is 15,000 MJ of energy. The energy flow of the environment contains the energy received by plants from the soil and the atmosphere, and the energy of solar radiation. The structure of the flow of direct energy spent on growing corn contains labor inputs using various machines, mechanisms, as well as costs of electricity and heat.

Rape is a very valuable forage crop. 100 kg of rapeseed meal contains an average of 90 feed units. The digestibility coefficient of organic substances reaches 71%, while sunflower meal – 56%. Rapeseed meal predominates sunflower's one in the content of essential amino acids: lysine by 33%, cystine by 2.1 times. A ton of rapeseed meal or cake allows to balance 8-10 tons of grain by protein, thus increasing the content of digestible protein in one feed unit from 80 to 110 g.

With a rape yield of 20 centners per hectare, the yield of biodiesel will be 800 kg/ha, which is equivalent to 40,000 MJ of renewable energy. In the structure of the total energy in the technological process of growing rapeseed with such a yield of seeds, the costs for tillage, seed and sowing will be 12%, the introduction of mineral fertilizers – 48%, the use of plant protection products (herbicides and insecticides) – 10%, harvesting, transportation, drying up of seeds, payment, depreciation, etc – within 30%. The total energy expenditure is 30 MJ of energy. Thus, due to biodiesel fuel obtaining, the incremental inflow of renewable energy will be 10,000 MJ of energy.

The high energy balance also can be provided with bioethanol production from beet molasses – 3.17. Calculations are given in Table. 6.5.

Table 6.5

Energy Balance of Energy for Bioethanol Production

Indicator	Type of raw material	
	Corn	Molasses
Expenses of anthropogenic energy in the production of raw materials for bioethanol according to standard technologies	50.591 MJ/ha = = 15 566 MJ/t (with corn yield 32.5 c/ha)	4.5 MJ/ha
Energy costs for raw materials per 1 ton of bioethanol	15566 x2.9 = 45141 MJ/t bioethanol	4,5x4,22 = 19 MJ/t of bioethanol
Energy costs in the production of bioethanol	11424 MJ/h	9440 MJ/t
Total energy for the production of 1 ton of bioethanol	56565 MJ/t	9459 MJ/t
The amount of energy obtained by using 1 ton of bioethanol	30000 MJ/t	30000 MJ/t
Energy output from production of 1 ton of bioethanol	26565 MJ/t	20541 MJ/t
Energy efficiency of production of 1 ton of bioethanol		68.5%

The data of Table. 6.5 indicate that the use of 1 ton of bioethanol from molasses provides more energy (by 68.5%) than was spent on its production. In other words, the energy output from production is 20 541 MJ/t of bioethanol.

The energy output from the production of 1 ton of bioethanol from corn largely depends on the average yield of this crop from 1 hectare of land area. The production of bioethanol from corn will not be energetically effective if its yield is less than 32.5 c/ha.

6.4. Modern Approaches to Economic Research of Bioenergy Technologies

The path of Ukraine and its agro-industrial complex to processing agricultural products from biological fuel and energy components is inevitable and choiceless. The government should not stay aside from creating bioenergy technologies, were as this would mean an economic backwardness of development, a low international competitiveness of the economy.

State agrarian priorities along with other areas are realized through the development and implementation of a program for the development of diesel biofuel production. The priority task is the improvement of scientific support for the development of the agricultural sector in the implementation of resource-saving, safe and environmentally friendly technologies for the production of agricultural products and food, creating conditions for the production of equipment that will ensure the use of modern, high-performance technologies, an effective combination of national and Regional policy in the agrarian sector.

Assessing the prospects of scientific provision, creation of bioenergy technologies for the production of raw materials and biofuels on innovative principles, it should be noted that the Cabinet of Ministers of Ukraine adopted the Resolution "On Approval of the State Target Program on Village Development of Ukraine for the period till 2015". It notes that the formation of an investment-innovative model for the development of the agro-industrial complex should be ensured from outstripping growth rates of investments through internal and external sources, the development of the market for innovative products, rational placement and deepening of specialization and concentration of crop production in the country's natural economic zones, state support, directly concerns the creation of bioenergy technologies.

Bioenergetic technologies are oriented towards transforming the achievements of science in the interests of creating a highly effective product, ensuring the competitiveness of agriculture on the domestic and foreign markets, and ensuring the country's food security. All the features signs of conventional technologies are inherent and bioenergetic, with the exception of the fact that they have an ultimate performance of exceeding the usual ones in 1,5-2 and more times. Considering bioenergetic technology in a new dimension, it should be noted that it is mainly oriented to outrunning growth rates of the most innovative factors available for use.

Beyond the obtained scientific achievements in the production of raw materials and biofuel, there are some unresolved problems: the determination of ef-fective and factor attributes in the modeling of bioenergy technologies and the clarification of cause and effect relationships, and the construction of a mathematical-statistical apparatus for the model of bioenergy technology.

When disclosing the essence and content of the scientific provision of bioenergy technology for the production of fuel and energy components on innovative principles, there is an obvious question: what is it? It is important that it simultaneously relies on two fundamental innovative foundations: the properties of soils and the characteristics of climatic conditions and the ability of energy-intensive varieties of crops to respond adequately to the conditions of use. Moreover, it turned out that it is expedient to estimate the bioenergetic technology through the indicator of the total oil-equivalent energy intensity of one hectare of bioenergy technology in points.

It is legitimate to give it bioenergy status only when, by its effectiveness, it exceeds the average values of conventional technologies by 1.5-2 and more times, which makes it possible to distribute the crop in such proportions: within the average values of conventional technologies for food needs, and the rest – for the production of fuel and energy components. To illustrate the typical causal relationship between the features of bioenergy technologies, we will perform cal-culations using the example of 10 selected technologies of multiple correlation of the type:

$$yx_1x_2 = a + bx_1 + cx_2,$$

We solve the system of normal equations by the method of least squares

$$y = na + bx_1 + cx_2,$$

$$yx_1 = ax_1 + bx_1 + cx_1x_2,$$

$$yx_2 = ax_2 + bx_1x_2 + cx_2,$$

In this example we uncovered that:

y – total oil-equivalent energy intensity of one hectare of bioenergy technology has the following values (in points): 9, 10, 12, 14, 15, 16, 18, 19, 21 and 22 (as a result);

x – synthetic assessment of the soil-climatic potential of one hectare of crops of crops (in points).

The National Research Center "Institute of Soil Science and Agrochemistry named after AN Sokolovsky" performed soil assessment of Ukraine with the involvement of the following parameters: the particle size distribution and humus content, which form the structure, soil structure and ratio in it in different sizes, -thermal and nutritional regime in critical periods of plant development and their harvest, etc. Therefore, it is necessary to evaluate the holistic system "soil-climate" and only under such conditions it is possible to obtain the most objective soil assessment. The results of soil and climate assessment are summarized in the so-called synthetic yield class, which has a wide range of values.

Taking into account the published material, it is assumed that x, or a synthetic assessment of the soil-climatic potential of one hectare of crops, can have the following values (in points): 33, 37, 33, 46, 39, 50,51, 39, 50, 53 (Factor sign);

X_2 – how the energy intensity of one hectare of planting crops is the following: (in points): 6, 8,12,10, 8, 134, 12, 17, 14, 20 (factor).

To determine the result, we construct Table 6.6.

Table 6.6

Indicators for Determining the Value of the Effective Indicator

No.	y	x_1	x_2	yx_1	yx_2	x_1x_2	x_1	x_2
1	9	33	6	297	54	198	1089	36
2	10	37	8	370	80	296	1369	64
3	12	33	12	396	144	396	1089	144
4	14	46	10	644	140	460	2116	100
5	15	39	8	585	120	312	1521	64
6	16	50	13	800	208	650	2500	169
7	18	51	12	918	216	612	2601	144
8	19	39	17	741	323	663	1521	289
9	21	50	17	1050	294	700	2500	196
10	22	53	20	1166	440	1060	2809	400
	156	431	120	6967	2019	5347	19115	1606

Substitute the corresponding values from the table and calculate the parameters of the equation:

$$156 = 10a + 431b + 120c \quad ;$$

$$6967 = 431a + 19115b + 5347c \quad ;$$

$$2019 = 120a + 5347b + 1606c \quad .$$

Divide the terms of the equation by the coefficients of a and obtain:

$$15.6 = a + 43.1b + 12.0c \quad ;$$

$$16.2 = a + 44.3b + 12.4c \quad ;$$

$$16.8 = a + 44.5b + 13.3c \quad .$$

When the first equation is subtracted from the second, the resulting equation is

$$(16.2 - 15.6) = a - a + (44.3 - 43.1)b - (12.4 - 12.0)c \quad ;$$

$$0.6 = 1.2b + 0.4c \quad ;$$

When the third equation is subtracted from the second, the resulting equation is

$$(16.8 - 16.2) = a - a + (44.5 - 44.3)b - (13.3 - 12.4)c \quad ;$$

$$0.6 = 0.2b + 0.4c \quad ;$$

We obtain a system of two equations with two unknowns:

$$0.6 = 1.2b + 0.4c \quad ;$$

$$0.6 = 0.2b + 0.4c \quad .$$

Divide each equation by the coefficients of b:

$$0.5 = b + 0.33 \quad ;$$

$$3.0 = b + 2.0c \quad .$$

When the second equation is subtracted from the first, the resulting equation is

$$-2.5 = -1.67c;$$

$$c = -2.5 - 1.67;$$

$$c = -4.17.$$

Substitute the value of c into any of the two equations:

$$3.0 = b + 2.0 \cdot (-4.17) \quad .$$

$$b = 11.34.$$

After this, we substitute the value b = 11.34 and c = –4.17 in the equation:

$$15.6 = a + 43.1 \cdot 11.34 + 12.0 \cdot (-4.17);$$

$$15.6 = a + 488.75 - 50.04;$$

$$a = -423.11$$

Then we will have an equation:

$$yx_1x_2 = -423.11 + 11.34x_1 - 4.17x_2,$$

Thus, with some conventionality, it can be argued that with growth of synthetic assessment of the soil-climatic potential of one hectare of sowing of agricultural crops by 1 point-grade, the value of oil-equivalent energy intensity of one hectare of bioenergy technology is growing by 11.34%, and an increase in the oil-equivalent energy intensity – by 4.27%. In this case, when scientific support for the creation of bioenergy technologies for production of raw materials and biofuels on innovative principles of priority is given secondarily by the value of x_1 and, first of all, by x_2, which corresponds to requirements of the bioenergy technology mentioned above. Here, x_2 is an innovative factor.

Such technology for the final result should prevail in conventional 1.5-2 and more times. First of all, it provides a sufficient supply of food security, and secondly, guarantees an excess of production that can be used for receiving the fuel and energy components.

6.5. Clustering of Biofuel Production as the Way to Energy Security of Ukraine

The formation of the "new economy" – the knowledge economy as the main source of high economic growth in many European countries provides an increase in GDP, an increase in export potential, a reduction of production costs that determine not only the development of economic sectors, but also the qualitative transformation of society. An important feature of the innovation-oriented economy is the formation of production clusters.

The depth and scope of the spheres of activity of cluster structures has increased especially in recent years with the growing processes of globalization, the intensification of competition and the deterioration of the situation on world markets. The ability to form critical mass in certain spheres of activity by clustering allows clusters to present to the world both the uniqueness and the ability of any national, regional or territorial economy to withstand pressure from competitors.

In recent years, theoretical developments to create clusters of small enterprises, dairy and meat processing complexes have emerged. The structures of various industries actively cooperate and assist in the development of each other. But the cluster system is not yet sufficiently developed and has not been widely used.

Clusters can cover both a small (10-15 companies) and a significant number of enterprises and structures (6-7 thousand companies, as in India or China), and can also be formed from both large and small firms in different types of associations and relationships. Cluster is considered as a geographical concentration of companies operating in a separate type of business, as well as a conglomeration of large and small firms, some of which may be the property of foreigners. Clusters form both in traditional industries, and in the production-commercial segment or in the service sector and social spheres.

Often, the center of formation of clusters is universities or groups of research structures and design institutions. Different clusters have an unequal degree of interaction between the firms that enter into them. The forms of such interaction vary from relatively simple, network type, associations to complex, multi-level cooperative-competitive entities. The formation of clusters is possible both in a large-scale and in a small economy. Clusters are formed not only in the conditions of industrially developed states, but also in those countries that are still on the way to this. They arise at the national, regional and municipal levels. Such a wide range of forms and types of cluster structures, of course, creates significant difficulties in the formation of clusters, requires consistent research in this area. Clusters as a kind of complex multi-centered organization of production systems in the era of globalization is a typical market structure.

The analysis of the literature sources, highlights both world and Ukrainian experience, testifies the advantages of production systems based on the cluster model. In particular, clusters are:

- able to provide a combination in the production of competition with co-operation, they personify "the collective effectiveness", create "flexible specialization";
- formed using a scale effect;
- points of growth, stimulators of technical progress;
- the mechanism for increasing regional and national competitiveness.

Clusters help to make stronger the processes of specialization and division of labor between partners, inter-firm flows of ideas and information;

- attract a broad clientele, create a close interaction of buyers and sellers;
- reduce the cost of a unit of technical service and products, which is made on the basis of proximity, joint activities;
- stimulate the innovation of production, the creation of new jobs;
- ensure a balance of market efficiency and social harmony.

Everyone who engages in business in Ukraine, realizes how many obstacles exist on the way to success in this complex matter. One of the key problems in mastering the cluster model is the identification and isolation of a particu-lar scheme of production relations of the named network form from many types of cluster connections, including territorial proximity, social differences, technology peculiarities, directions of production flows, etc. It is the degree of proximity of cluster members to the listed components that determines the strength and the efficiency of the motivated functioning of the named particu-lar cluster production system.

Clustering, as our research shows, is a real embodiment of the belief provided by logic that the unification of efforts close to the above-mentioned characteristics of production gives them an advantage over those business structures that work separately.

The most clear characteristic of the cluster is the background of local "buyer-supplier" relations. Most firms buy raw materials, components, services in other local firms. Having a common network of suppliers and buyers is a great advantage for participating firms in similar locations. An essential part of the cluster interrelations is the activity of the "value chain" formed by the cluster, its functioning makes it possible to ensure that the competitive advantages of firms depend on the activity of their activities, from project development, materials procurement, product manufacturing and, finally, logistics of their sale and service. Since a large number of these operations require extensive interaction between buyers and other entities, the geographical location of companies is a very important factor for each link in the value chain and for development strategies.

Ukraine has a huge potential for almost all types (solar energy, wind energy, biomass, biofuel, geothermal energy, microhydroenergy) of renewable energy sources. The use of this resources implies obtaining a great potential according to the world trend of using renewable energy and taking into account the Kyoto Protocol, which Ukraine signed with other countries.

Now, the share of biomass in energy supply in Ukraine is about 0,5%. Currently, about 0.7 million tons of fuel equivalent are used in terms of oil. According to the Institute of Technical Thermodynamics of the National Academy of Sciences of Ukraine, our country can satisfy within 95% of the volume of primary energy consumption.

In general, the current state of biofuel production in Ukraine is characterized by a high imbalance between the suppliers of feedstock and its processing, between processing enterprises and sales structures. Insufficient financing for replenishment of current assets through lending and investment in new projects, and deterrence of domestic and external innovations are among the main causes of the depressed state of involvement of renewable energy sources in production processes.

The cluster of biofuel production is a stable territorial-intersectoral part-nership united by an innovative program of application of modern production, engineering and management technologies with the aim of increasing the competitiveness of its participants.

Most developed countries, for their scientific priorities in the production of biofuels, are looking for ways to use renewable energy stored by living matter through photosynthesis. Particular attention is paid to energy crops and plant biomass, which have significant advantages over fossil carbohydrates. To conserve natural resources and improve the environment, science offers a closed cycle of exchange of energy consumption and reproduction. This requirement is met by the use of fuel based on bioethanol and biodiesel, which have occupied a significant segment of the world energy market, and each year it is becoming increasingly important. Thanks to the burning of biofuels, a natural metabolism takes place – carbon dioxide (CO_2) is absorbed again by the plants.

The production of biodiesel fuel is mainly increased due to rape and soybean oil, and bioethanol is mainly due to corn and other grain crops. This was facilitated by the relevant directives, which, on the one hand, regulate the mandatory use of impurities for ethanol and biodiesel fuels, and on the other, the creation of economic conditions to facilitate the production of these energy sources. The technological process of processing seeds into biodiesel provides a clear organization of material flows, a clustering of legal entities (Figure 6.1).

One of the most potential and unused sources of renewable energy for Ukraine is the production of liquid biofuels from biomass (crops, wood cultures, herbaceous plants).

The soil and climatic conditions of Ukraine are favorable for the production of agricultural crops as a biosource in all regions: corn, triticale, winter wheat, various kinds of sorghum, millet, sugar beet, sunflower, rape, and the use of agricultural and forestry wastes. Potato accumulates more energy per hectare

Figure 6.1. Cluster of Legal Entities for the Production of Biodiesel

area under our conditions, however, the problem of its storage for a long time before processing has not been resolved.

In Ukraine, there are opportunities to use a sufficient number of capacities of alcohol, sugar, yeast plants and workshops, as well as fat-and-oil plants for biofuel production. So the total potential capacity of distilleries now is about 600,000 t per year, the needs of Ukraine for excisable (food, perfume) alcohol is 250-300 thousand t. The existing "extra" distilleries can theoretically produce about 300 thousand t of bioethanol.

Internal bioethanol market may reach 800-1200 thousand t per year if it replaces 10-15% of the hydrocarbon part of gasoline consumed in Ukraine. The European space is even more potential for the export of bioethanol.

To create a strategic management system for clustering processes in the sphere of biofuel production, it is necessary to analyze organizational and technological changes, identify key success factors, develop a clustering mechanism for the regions, and monitor the development of clusters in the regions in order to take measures to ensure their livelihoods and development in the future.

Clustering as the basis of the agrarian policy of the region should focus on the primary development of agricultural production in the most developed regions, without reducing the level of production in other areas. On the basis of the developed strategy of agrarian production of the region, it is necessary to determine the potential of the level of development of the district, in particular, the availability of a resource base, labor resources, transport infrastructure, innovative projects for the development of agriculture and processing enterprises. The above criteria will make it possible to determine highly prospective, middle-perspective and insufficiently promising areas, that is, to determine the stage-by-stage formation of clusters for the production of biofuel.

Undoubtedly, the solution of the problem of dynamic development of clusters for the production of biofuels is closely correlated with the decision of food security. On this occasion, there is a constant discussion: what is more important – food or biofuel? This problem is very difficult, because, on the one hand, providing the population with food is a priority for every government, and on the other hand, the energy independence of the state is the basis of its sovereignty. Therefore, the analysis of the possibilities for growing bio-raw materials for biofuel production should be carried out, taking into account the real situation both of existing needs for food products and of existing sources of fuel supply to the state and its individual regions.

Thus, Ukraine has encouraging conditions for the formation of clusters for the production of alternative fuels. The alcohol industry has an extremely powerful and large number of underdeveloped plants that can occupy an important niche in the production of bioethanol. The industry of biodiesel fuel production is developing. At the same time with the transition to the use of biofuels, it is necessary to modernize the filling stations and the distribution network, and also to interest the domestic oil traders who own the gas stations in the entering to this market. The entry of new participants into the market of refueling services, which are owners of distilleries or fat-and-oil plants, creates competition for powerful giants, each of which has sufficient revenues in its field to defend its positions.

The combination of enterprises in regional clusters with a closed production cycle of biofuel production under the scheme "production of bio-raw materials – processing of bio-raw materials – production of biofuels – biofuels" with well-planned production planning and centralized financing of all works for the production of bioenergy raw materials and biofuels allows creating appropriate conditions for the stable operation of joint enterprises and reducing the cost of production of biofuels by placing corporative orders in these enterprises.

For example, to form a cluster for the production of biodiesel, it is advisable that it includes such profile enterprises and institutions:

- scientific and educational institutions that carry out scientific research on the problems of production of alternative fuels;
- rapeseed farming enterprises, where its production will not be the main type of product, but the order for a certain quantity of commercial rapeseed seeds for loading capacities of cluster enterprises processing seeds for oil;

- the plants for processing seeds for oil, where the production of rapeseed commercial oil for this enterprise is not the main product, but only the order of the cluster for a certain amount of oil for loading the cluster's biodiesel production facilities;
- manufacturing companies that process oil for biodiesel, where biodiesel production will be the main product (biodiesel producers)
- enterprises that sell biodiesel.

The cluster integrator for the production of biodiesel can be scientific and educational institutions or enterprises producing biofuel.

The production of biodiesel fuel is planned by cluster formation in such way that the mutual settlements between its enterprises determine the stimulating nature of the production of bioenergy raw materials, namely:

- to reduce the energy component of the prime cost of the main products (including rapeseed itself), cluster enterprises producing biodiesel fuel are, first of all, transferred to agricultural enterprises that are members of a cluster formation and specializing in seed production, at a cost of cost value of its products (biodiesel fuel) in volumes that can covere the energy needs of these enterprises;
- the processing enterprises producing rapeseed oil, first of all, have to transfer a part of their by-products at the cost price level to the seed producing enterprises – cake in quantities that basically covered the requirements for feed of these cluster seed producing enterprises.

This integrated approach to solving the problem of mutual settlements and simultaneously pricing for biodiesel makes it possible to significantly reduce the main components of the cost of biodiesel fuel by achieving an increase in the yield of rape from 1 hectare of sown area, reducing the cost of its cultivation, reducing the cost of processing rape for oil, producing by-products other than biodiesel. Fuel, products of rape processing – food, fodder, pharmaceutical and other directions.

Within the cluster association of producers and processors of bioenergy feedstock in most regions of Ukraine on the basis of complex multifunctional technological lines, it is possible to include the production capacities of economic entities of all forms of ownership and management for growing high-energy crops and their processing. This will contribute to the building up of land resources for the production of bio-raw materials, the creation and development of an industrial infrastructure for growing rapeseed, the creation and development of an infrastructure for the production of rapeseed oil, biodiesel and the infrastructure for the use of biofuels in the transport sector.

In the current financial and economic situation in the agrarian sector, state support is needed for the development of biofuel production on the basis of clustering to protect it from the risks at the stage of the pilot project and in the first years of the clustering of the bioenergy industry in Ukraine.

6.6. Formation of Market Infrastructure in Biofuel Production

The development of biofuel as an economically viable alternative to hydrocarbons, which can partially replace them, and therefore contribute to the diversification of the national basket of energy resources, naturally determines the formation of the biofuel market infrastructure.

Biofuel market formation is a complex and long process. It is linked with the economic and social progress of society in the developed countries. In Ukraine, when the biofuel market makes the first steps of its formation and development, like any objectively existing system, it certainly must have its own developed infrastructure. However, today it is one of the most developed components of biofuel production.

The problem of infrastructure forming in serving the agribusiness market system is considered from the perspective of organization of the sphere of circulation of goods, without taking into account a set of specific institutions that perform the functions of specialized services to business entities for further integration into a single economic macrosystem. Insufficient attention is paid to the formation of market infrastructure in biofuel production.

The market economy is based on three main "whales": the legal system (property rights), market infrastructure and entrepreneurship. It is an unsurpassed economic mechanism with a human who cares about one's own interests and creates material values for others. Adam Smith, in his famous work "*An Inquiry into the Nature and Causes of the Wealth of Nations*", and also in other works, showed that the personal interest of each person as a member of society, based on the division of labor, leads to the maximum possible benefits for society as a whole. Prerequisites for this are property, competition, market, business environment.

Concerning the market economy, the concept of "infrastructure" was first used by R. Jochimsen, defining it as the sum of material, institutional and special conditions placed at the disposal of economic entities and create the conditions for full integration and ensuring the maximum possible level of development of economic activity.

With the development of science and the accumulation of experience, it was established that: the higher the level of infrastructure development, the faster and more investment flows, more labor is attracted, economic development is accelerated, and the living standards of population are growing. Conversely, the lower is the level of infrastructure development, the slower or more costly the production develops, the more difficult is the life of people.

In modern economic literature, there are various interpretations of the concept of "market infrastructure". Most often it has been distinguished three groups of concepts of market infrastructure.

Group I. Market infrastructure as a complex of industries, sub-sectors and spheres of activity, the main task of which is to prove the goods from production to consumers.

Group II. Market infrastructure as a market framework is an extensive and interdependent network of enterprises and farms for servicing the exchange and movement of goods.

Group III. Market infrastructure as a set of technical equipment and equipment that support market processes.

As the market is a way of interaction of economic entities based on the price system and competition, e.i. a special mechanism for coordinating economic actions, the infrastructure relative to biofulsmarket is a system of state, private and public institutions (organizations and entities) and technical means serving the interests of the subjects of production biofuels, ensure their effective interaction. Among them there are brokerage firms, various exchanges, invest-ment companies, banks, leasing companies, employment centers, insurance organizations, etc.

The infrastructure of biofuel production has its own characteristics. It has a multichannel production of raw materials, biofuels, products, a wide range of infrastructure elements that change significantly over time, the creation of specialized institutions that provide a logistics system for collecting raw materials and transporting it, integrating biofuel institutions with existing fossil fuel infrastructure institutions, network of municipal fuel stations and so on.

Creation of goods occurs in the process of biofuels production, and it requires bringing them to consumers. This involves the organization of the sphere of circulation of goods, i.e. the totality of the institutions of infrastructure that ensure the circulation of various goods, mutually beneficial economic relations between producers of goods and their direct consumers.

So, the biofuel production infrastructure is a set of specific institutions that perform the functions of providing specialized services to business entities in the sphere of biofuel production with the aim of creating favorable conditions for functioning, best realization of their interests and subsequent integration into a single economic macrosystem. The main macroeconomic function of the biofuel market infrastructure is to increase the efficiency of using the capi-tal of the relevant economic entities and the biofuel sector in general.

The product of the infrastructure is an intermediary service. Service is a special commodity, that exists only at the time of its production. Providing various intermediary services to enterprises of bio-raw material and their producers and consumers, the infrastructure institutions must perform a number of important functions to ensure integration and intra-industry processes for the production of alternative fuels and to bring the goods to the direct consumer, i.e. to help not only organize production, but to ensure its implementation. Specialization in intermediary operations allows to reduce the time for the sale of goods, reduce the costs of circulation, accelerate the turnover of the enterprise's funds, consider the requests of consumers.

As infrastructure institutions are under the influence of both the producer (the supply of goods) and the consumer (the demand for it), then analyzing the progress of a certain product on the market, the intermediary must identify trends that allow for better targeting production to the interests of consumers, redistribute resources between different branches. This function is provided both through a reorientation to the release of new products, and for its improvement.

The formation of the biofuel production infrastructure cannot have a systemic character and be a successfully operating structure without the functioning of its important elements, in particular auctions, chambers of commerce, trade houses, fairs, stock exchanges, brokerage, insurance, audit firms, holding companies, etc.

Auctions as the forms of goods sale at a certain time and place, previously exhibited for inspection, sell certain types of goods, which are usually in high demand.

Chambers of commerce and industry are commercial organizations whose main task of which is to promote the development of economic and trade ties with part-ners of other countries. They are legal entities, operate on the principle of full commercial calculation and self-financing. Chambers of commerce and indus-try provide purpose-oriented information services.

Trading houses are trading firms that purchase goods from producers or wholesalers of their country and resell retailers and consumers abroad and buy goods abroad and resell local wholesale and retail traders and consumers in industry and other branches of the economy.

Until recently, fairs have been considered as an extremely important element of market infrastructure. These are trades, commodity markets, which are periodically organized in the established place. They played an important role in the economic life of the countries of Western Europe. With the development of social production, the expansion of trade and exchange operations, the intensification of competition from the centers, the importation of large quantities of the available goods, the fairs turned into exhibitions of samples of goods that can be ordered.

An important institution with the most optimal consequences for partners in selling of goods, with a uniform strategy of commercial behavior of agents, is the exchange. This is the organizational form of the market with free trade in goods and services. It forms overall price situation of the market and the rates of the corresponding assets for all market entities on the basis of the actual supply-demand ratio.

In the early 20th century, four main types of exchanges were formed:
- the first is available for all;
- the second is a closed, comprehensively regulated by the state;
- the third is a comprehensively state-regulated corporation;
- the fourth is a free corporation or its private company.

All types of exchanges have certain features, but they are united by the fact that they improve and facilitate market relations, regulate and order (through written and unwritten rules) active agents of market economy, connect them with each other, facilitate the transfusion of capital, are indicators of market orientation.

To carry out operations on the exchange, three variables should be fixed: the price, the amount and the delivery time. Recently, futures transactions (agreements on the sale of goods that will be produced in the future) are getting more intensive in the work of exchanges.

They do not provide for the quantity of goods, contracts. When concluding futures, only two positions are agreed: price and delivery time. Such agreements may concern only one standard type of goods (the so-called base grade) established by this commodity exchange.

The formation of a dynamic system for the production of biofuels with market orientation, based on the principles and laws of commodity production, requires the establishment of effective marketing activities of the biofuel complex. It is necessary to involve the main components of marketing: the production of products based on knowledge of the needs of consumers, the market situation and the real possibilities of the corresponding production; the most complete satisfaction of the needs of the buyer with the use of methods of price and non-price competition.

Effective sales of products and services on specific segments of the biofuel market on the basis of comprehensive consideration of supply and demand and supply-side capacities of economic entities producing biofuel, ensuring the long-term capacity of industrial commercial enterprises, firms and organizations on the basis of operational use of scientific and technological developments, as well as know-how in the field of biofuel production are mandatory for all marketing concepts.

The choice of the structure of marketing activities depends on the nature of the production of bioproducts by the subjects of entrepreneurial activity and its realization on the domestic and foreign markets. At the same time, the important function of marketing services is the segmentation of the market, i.e. the differentiation of buyers depending on their needs and behavioral features, tracing the movement of prices and sales volumes of both bio-raw materials and alternative fuels, and the variety of forms of regulation of commodity-money relations.

The strategic task of Ukraine – a member of the WTO – is the formation of an infrastructure for the development of the biofuel market, which should be directed at overcoming the reasons that obstruct to create energy security.

The implementation of structural reforms with the purpose of expanding communication services and improving their quality is an urgent issue as well as creation of technical base of informatization, development and modernization of zonal and local networks on the basis of modern technologies.

To stimulate scientific, technical and innovative activities in the field of biofuel development, it is necessary to ensure the development of innovative infrastructure, i.e. innovation and investment institutions that contribute:

- creation of a system of preferential refinancing of commercial banks in case of granting them preferential loans for the implementation of investment projects for the development and implementation of high-tech equipment and other innovative products in the field of biofuels;
- expanding the practice of concessional lending on the security of property of business entities;
- creation of mutual investment funds for implementation of large innovative and investment projects for the development of the biofuel market;
- a variety of forms of lending to innovative enterprises through leasing, factoring and other operations;
- cheapening of credit resources for introduction of innovations;
- introduction of the state order for innovative products;
- settlement of issues related to the acquisition and use of ownership of the

results of scientific and scientific and technical activities, which is carried out in full or in part at the expense of public funds.

6.7. Social and Ethical Marketing Direction of the Agrarian Sphere

One of the most important prerequisites for the development and practical implementation of the agrarian policy is the awareness of its regulatory and legal framework. Agrarian policy can be considered effective if it ensures the fulfillment of individual tasks.

By definition of V. Bilyk and P. Sabluk, a market is an exchange organized according to the laws of commodity production and circulation; the aggregate of specific economic relations between producers and consumers; a special socioeconomic structure, the main functions of which is the exchange of goods. Markets are able to react objectively to the needs for goods.

At the same time, as I. Mihasyuk, A. Melnik and other authors note, there is no ideal market. Often the mechanism of market self-regulation does not fulfill the functions assigned to it. Do we should not ignore the fact that the production rela-tions are often changed and the ideas about the market, including the market of energy-intensive raw materials, are also change.

One of the central ideas of the scientific works of the authors is the need for the systematization of knowledge, the formation of pioneering research areas, the growth of production and use of biofuels.

However, the foregoing, of course, should not be interpreted unambiguously. The analysis convincingly shows that at the current stage a wide range of problems in the sphere of production and consumption of biofuels has attracted little attention of scientists, namely: the lack of equivalence between the production of feedstock and biofuels, the discrepancy between the volumes of feedstock and the technical and technological base of processing enterprises.

With the mechanism formation of the energy-intensive crops market for biofuel production, first of all, it is necessary to disclose such aspects: the formation of a conceptual apparatus for the problem of biofuel production; deepening the compromise between crops, which are directed to biofuel production and food needs; structuring the system of food and energy security as a single instrument for regulating the market of feedstock.

There is a need to build a new type of agribusiness in the agro-industrial complex, which is primarily oriented towards an innovative model of development, where the methodical scientific factor plays a decisive role. Besides, there is a necessity to develop a modern mechanism for developing a market for energy-intensive crops for biofuel production, forms of harmonizing the production of energy-intensive crops (corn, spring barley, sugar beet, rape, etc.) and the capacity of industrial enterprises for the production of biofuels in order to prevent disruption of the proportions between industries, as well as methods for extrapolating production of raw materials for the future.

Let's consider the economic mechanism of social and ethical marketing in the bioethanol production sphere. In order to do this, we should:

1) formulate the essence and concept of the market development of energy-intensive crops used for the production of bioethanol;

2) draw attention to the procedure for determining the reliable (homogeneous) average yield of maize, spring barley and sugar beet for the justification of the technologically-model parameters (capacity) acceptable for the size of industrial enterprises for the processing of agricultural raw materials and the production of bioethanol;

3) develop methodological bases for determining trends in the development of gross harvest of maize, spring barley and sugar beet, and on this basis to outline possible options for increasing the agreed volumes of feedstockand bioethanol in the future;

4) determine the place and role of the mechanism for the development of the market for energy-intensive crops for the production of bioethanol in providing individual components of food security and the appropriateness of us-ing it in the context of the state energy security.

The real situation of the agro-industrial complex in the sense of the concept of "development" in general and regarding the market of energy-intensive crops for the production of bioethanol largely does not meet the requirements of the time, because the economic factors that shape and influence the current production processes, have not received an unambiguous interpretation today. Such variants of interpretation as "development", "sustainable development", "stable development", "growing development", "progressive development" and others are often encountered. Such ambiguity of the analyzed concept cannot contribute to improving the way of disclosure of certain processes.

The modern problem of substantiating the concept of «development» in the field of bioethanol is a traditional and radically new at the same time. The rationale is traditional, as it is aimed at improving energy security as a key force. At the same time, it is fundamentally new that scientific research is supported by new scientific methods that are basic for the development of fundamentally new scientific knowledge about the development processes in general and the development of the bioethanol market in particular.

What conclusions are followed from the above? Considering this is-sue, we should adhere to the thesis that development can be characterized in different ways: taking into account the dynamics of time, quantitative indicators, indicators that can not be quantified. The process of transformation of phenomena in the sphere of bioethanol in time is expedient to cause dynamic development. The analysis of dynamic development, as a rule, should be carried out on the basis of multidimensional statistical series. They allow us to assess the intensity and describe the nature of the development of all the components, carry out a comparative analysis of the dynamics of two or more processes, assess the influence of the intensity of development of some processes on others, and build scientifically based forecasts.

If the growth rate is more than one or equal to 100%, then this indicates the growth of a process, and when there is less than one or 100% – there is not a growth rate, but a rate of decline (decrease, reduction).

On the procedure for determining reliable (homogeneous) average yields of maize, barley and sugar beet in order to justify the technologically acceptable model parameters of industrial processing of agricultural raw materials for bioethanol, special calculations are needed for this (Table 6.7).

Table 6.7

Calculation of Indicators of Variation in Yields of Crops Used for the Production of Bioethanol

Position number	Agricultural crops								
	maize			barley			sugar beets		
	yield, t/ha			yield, t/ha			yield, t/ha		
1	2.8	-0.3	0.09	2.1	-0.03	0.09	23	1	2
2	2.9	-0.2	0.04	2.7	0.3	0.09	21	-1	2
3	3.2	0.1	0.01	2.9	0.5	0.25	18	-4	16
4	3.5	0.4	0.16	2.7	0.3	0.09	24	2	4
5	2.5	-0.6	0.36	1.7	0.7	0.49	18	-4	16
6	2.9	-0.2	0.04	2.3	-0.1	0.01	21	-1	1
7	3.7	0.4	0.16	2.2	-0.2	0.04	29	7	49
total		2.2	0.86	16.8	2.4	1.06	154	20	90
averege	3.1			2.4			22		

Average absolute deviation formula:

$$L = \frac{\sum|x_i - \bar{x}|}{n}$$

$$L_1 = 2.2{:}\,7 = 0.31;\ L_2 = 2.4{:}\,7 = 0.34;\ L_3 = 20{:}\,7 = 2.8;$$

Dispersion formula:

$$\sigma = \frac{\sum(x_i - \bar{x})^2}{n}$$

$$\sigma_1^2 = 0.86{:}\,7 = 0.12;\ \sigma_2^2 = 1.06{:}\,7 = 0.15;\ \sigma_3^2 = 90{:}\,7 = 12.8.$$

Standard deviation formula:

$$\sigma = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n}}$$

$$\sigma_1 = 0.35; \sigma_2 = 0.39; \sigma_3 = 3.5.$$

Consequently, the value of crop yields has deviations from the average yield: corn – 0.31 t/ha, barley – 0.34 and sugar beet – 2.8 t/ha.

Thus, in terms of productivity, corn and sugar beet (given that yields are expressed in double digits) are homogeneous compared to barley.

The standard deviation is a measure of the reliability of the mean. The smaller the standard deviation, the more objective the arithmetic mean reflects the whole population. The mean squared deviation is typical for maize – 0.35, spring barley – 0.39 and sugar beet – 3.5 t/ha. The average squared deviations in corn and sugar beet are smaller, and therefore they objectively reflect the aggregate of the two crops.

We see that the foregoing phenomena are considered as phenomena of a resultant large number of unknown phenomena according to the law case. The random variable as a result of the experiments can take certain values, and previously unknown. It is important that this value is useful for estimating the statistical significance of the parameters of statistical models, constructing confidence intervals for the parameters of certain models.

In order to justify the technologically acceptable model parameters of industrial enterprises for processing agricultural feedstock for bioethanol, it is advisable to focus on the mean linear deviation, the mean squared deviation and the root-mean-squared deviation of corn. These methodical steps are designed to prevent the occurrence of disproportions between the volumes of agricultural raw materials that can be attracted for production, and the technological and model parameters of industrial enterprises that specialize in the processing of agricultural feedstock for bioethanol. It is advisable to adhere to the considered methodological steps not only at the initial stages of bioethanol production, but also in the future. The market, the production of feedstock and the production of bioethanol should develop according to an agreed option.

In order to disclose the essence of the methodological approach to determining trends in the development of gross yields of maize, spring barley and sugar beet, let us consider this with the example of gross harvest of corn. In the ranks with a clearly defined trend, it is described analytically with the help of a certain function:

$$Y_t = f(t) \tag{5.4}$$

t = 0, 1, 2, ... n is the time variation; Y_t – theoretical levels of the range.

We call this function the trend equation. Since absolute increments are used relatively reliably in the above calculations, we use the linear trend Yt = a + bt with stable growth rates – the exponential function Yt = abt. According to parameter b in the linear function characterizes the average absolute increase, in the exponential – average growth rate. The parameter a in both functions is the theoretical growth of the equation for t = 0.

It should be remembered that the parameters of the trend equations are calculated by the method of least squares, while non-linear functions lead to a linear form, for example, by the method of logarithm:

$$lqY_t = lqa + tlqb^t \tag{5.5}$$

Here the system of normal equations has the form

$$na + b\sum t = \sum y \tag{5.6}$$

$$a\sum t + b\sum t^2 = \sum ty. \tag{5.7}$$

If the origin of time is transferred to the middle of the range, so $\sum t = 0$, Consequently

$$a = \frac{\sum y}{n};\ b = \frac{\sum yt}{\sum t^2}; \tag{5.8}$$

and $\sum t^2 = \frac{1}{12}; n(n^2 - 1)$.

Next, calculate the linear trend according to Table. 6.8 on the example of gross harvest of corn grain. According to the tabular data, n=7, $\sum y = 39.5$, $\sum yt = 17.7$, $\sum t^2 = 28$.

Table 6.8

Gross Corn Grain Yield

Year	Gross corn grain yield, mln t	t	ty_t	Y_t	$y_t - Y_t$	$(yt - Yt)^2$
2000	3,0	-3	-9	3,8	-0,8	0,64
1980	4,4	-2	-8,8	4,3	0,1	0,01
1975	5,8	-1	-5,8	5,0	0,7	0,49
2005	6,1	0	0	5,6	0,5	0,25
2006	6,4	1	6,4	6,3	0,1	0,01
1985	6,5	2	13,0	6,9	-0,4	0,16
1990	7,3	3	21,9	7,6	-0,2	0,04
	39,5	0	17,7	39,5	X	1,6

Parameters of the trend equation are the following:

A=39.5/7=5.6; b=17.7/28=0.632

So, Y_t=5.6a + 0.632t, the average level of gross harvest of corn is 5.6 million tons, the annual gross harvest of corn will grow at average of 0.632 million tons.

Then

$$Y_{2000}^{x} = 5.6 + 0.0632(-3) = 5.6 - 1.9 = 3.8$$

$$Y_{1985} = 5.6 + 0.0632(-2) = 5.6 - 1.3 = 4.3$$

$$Y_{1975} = 5.6 + 0.0632(-1) = 5.6 - 0.6 = 5.0$$

$$Y_{2005} = 5.6 + 0.0632(0) = 5.6 - 0 = 5.6$$

$$Y_{2006} = 5.6 + 0.0632(1) = 5.6 + 0.6 = 6.3$$

$$Y_{1985} = 5.6 + 0.0632(2) = 5.6 + 1.3 = 6.9$$

$$Y_{1990} = 5.6 + 0.0632(3) = 5.6 + 1.9 = 7.6$$

If the conditions form a trend outside the dynamic range (trend extrapolation), the expected total grain yield of corn in 2008 was

$$Y_{2008} = 5.6 + 0.0632(4) = 5.6 + 2.5 = 8.1 \quad \text{mln t}$$

or

$$Y_{2008} = 7.5 + 0.0632(1) = 8.1$$

It should be noted that, there are serious discussions on the issues on defini-tion of the place and role of the mechanism for the development of the mar-ket for energy-intensive crops for the production of bioethanol in providing certain components of food security and the appropriateness of using it in the context of energy security of the agroindustrial complex.

Ensuring an adequate level of energy security and its irreversibility remains very important. The weakening of energy security can decline the food security.

World experience convinces that the increase in energy efficiency by one percent ensures GDP growth by 0.72 credit points. Therefore, the problem of using energy-intensive crops for the production of bioethanol in its content and form loses its meaning. It is quite natural and economically expedient to use energy-intensive crops as feedstock for the production of bioethanol. The issue can be violated only when clarifying the proportions and conditions for the rational implementation of such use.

The study of modern approaches of the formation of the mechanism for the development of the market for energy-intensive crops for the production of bioethanol allows us to assert that the concept of "dynamic development" in the production of bioethanol is appropriate to characterize given the time and quantitative measures. Dynamic development is dynamics and an estimation of influence of intensity of development of one processes on others and on the contrary; among three analyzed energy-intensive crops, namely corn (grain), spring barley and sugar beet (molasses), it is rational to use corn for the production of bioethanol. Such indicator as yield is characterized with the smallest values: the mean linear deviation, the mean squared deviation (dispersion), and the mean square deviation. That's why the values of food and energy security agree with each other in the production of bioethanol from corn. One security helps to strengthen the other and vice versa.

Basic definitions and concepts. *Crop rotation. Efficiency of cultivation. Biomass. Energy security of Ukraine. Food security. Energy balance. Evaluation criterion. Production of bioethanol. Biodiesel fuel. Economic research. Bioenergy technologies. Clustering production. Biofuel. Market infrastructure.*

Test questions and tasks

1. What is the main task of the state in the context of creating economic security?
2. What causes the need for rotation (alternately) growing plants?
3. How can plants be classified according to the response to crop rotation?
4. What are the types of crop rotation?
5. Describe the scheme of scientifically justified crop rotations for the growing of bioconcrete.
6. Explain how crop rotation affects crop yields.
7. Calculation of the output of biofuel from the total volume of individual agricultural energy crops in the application of crop rotations
8. What does the level of food security in Ukraine mean?
9. What is the area of arable land suitable for growing crops in Ukraine?
10. How many millions of hectares of arable land should be used to satisfy the needs of all residents of Ukraine?
11. What are the potential opportunities for growing grain in Ukraine?
12. Is there a threat to food security in Ukraine?
13. What is the balance of energy as a criterion for assessing production of bioethanol and biodiesel from grain and oilseeds?
14. What is the chemical composition of a dry after-alcohol bard derived from corn grain?
15. Describe the energy balance of energy for the production of bioethanol from molasses and maize.
16. Describe the latest approaches to economic research of bioenergy technologies.
17. Bring the technical and economic aspects of clustering biofuel production as a criterion for energy security in Ukraine.
18. Describe the cluster association of legal entities for the production of biodiesel.
19. Describe the formation of market infrastructure in biofuel production.
20. What is the economic mechanism of social and ethical marketing in the agrarian sphere?

CHAPTER 7
OTHER TYPES OF BIOFUEL

PART 1. SOLID BIOFUELS

Key issues

7.1.1. The Concept of Solid Biofuels and Its Global Significance
7.1.2. Feedstock for the Production of Solid Biofuels
7.1.3. Equipment for the Use of Solid Biofuels
7.1.4. Potential for Solid Biomass in Ukraine

7.1.1. The Concept of Solid Biofuels and Its Global Significance

Biofuels in the solid form has been in use ever since people discovered fire. Wood was the first form of biofuel that was used even by the ancient people for cooking and heating. With the discovery of electricity, people discovered another way of utilizing the biofuel. Biofuel had been used since a very long time for the production of electricity. This form of fuel was discovered even before the discovery of the fossil fuels, but with the exploration of the fossil fuel like gas, coal, and oil the production and use of biofuel suffered a severe impact. With the advantages placed by the fossil fuels they gained a lot of popularity especially in the developed countries. Liquid biofuel have been used in the automotive industry since its inception.

The most common type of biomass used as fuel is wood. The share of its consumption is 9% in the structure of world energy supply. Today more than 2 billion people in rural areas in developing countries use the energy of wood for cooking and heating. Thus, the use of wood as a fuel takes 1/3 of the world's share of renewable energy.

The history of pellets began in 1947. The owner of the sawmill, the American Rudolf Gunnerman, without technical education, invented an easy way for the export of his own production waste. To reduce transportation costs, the inventive entrepreneur decided to press wood waste, because in this form it is easier to compile and economically more expedient to transport. For a few decades, pellets began to be popular again, but already as an energetically attractive product. Europe, especially its northern part, has significant forest tracts and a technologically advanced wood processing industry on its territory. Therefore, remembering the practice of Gunnerman and its pellets, European countries, primarily Sweden, in the mid-80s of the 20th century, began to use a few decades ago invented method of pressing waste. This time is considered as the beginning of a new era in the solid fuel industry.

Currently, solid biofuels are defined as solid biomass, used as boiler fuel oil, including wood, peat, sawdust, chips, straw, other agricultural waste, pellets and briquettes made from biomass, charcoal.

Every year, consumption of such type of fuel, like briquettes, pellets and granules, is growing. Most of them are common in the USA, Austria, Germany, Denmark, Sweden, Norway, Finland.

Now, the EU is the main importer and consumer of pellets in the world and, according to the forecasts of the European Union of Pellet Producers (The *European Pellet* Council), the demand for solid biofuels will continue to grow in the EU (Table 7.1). The production of pellets is concentrated, first of all, in countries rich in forest resources, such as the USA and Canada, as well as in northern Europe (Sweden, Finland, Germany). However, as the consumption of solid biofuels increases, exporters are increasingly faced with the need to find additional raw materials. The amount of wood waste that has been used up to now is becoming inadequate. In addition, the crisis has reduced the volumes of the timber industry and the processing of wood all over the world, so the prices for raw materials have significantly increased. The main ways to solve the problem: planting fast-growing trees, importing sawdust and a fundamentally new product – agro-pellets. The feedstock for the production of the pellets is straw, sunflower and buckwheat husk, rice, woody parts of flax, rape, hemp, etc.

European countries are trying to encourage the population to use solid bio-fuels. In Germany, for example, each family receives a government subsidy of 1550 euros plus 50 euros for each kW of boiler output if they install a boiler for burning biomass.

Table 7.1

Volumes of Consumption and Demand Forecast for Pellets in Europe, thousand tons

Country	2011	2015	2020
Austria	710	1490	3500
Belgium	100	150	200
Denmark	700	1000	1250
France	560	1400	2500
Finland	70	150	450
Germany	1400	1900	3500
Ireland	40	60	70
Italy	1900	3100	4250
Spain	150	450	1150
Sweden	1000	1200	1400
Switzerland	160	250	400
United Kingdom	50	500	1250
Other countries	1100	1600	2200
Total	7940	13250	22120

The ecological advantages of solid biofuel use include:

– reduction of the greenhouse effect – carbon dioxide released in the process of pellet burning is qualified as "neutral". Wood releases the same amount of CO_2 athat is consumed in the process of growth (closed carbon exchange). When coal or oil is burned, CO_2 is released, accumulated over millions of years, increases its concentration in the atmosphere;

– reduction of acid rain – use of pellets contributes to reducing emissions of sulfur dioxide, which is the main cause of acid rain. Using pellets as a fuel, thereby reducing acid precipitation and preserving the forests with which acid rain causes the greatest harm;

– reducing the risk of transportation – pollution of the environment occurs almost continuously through holes in tanks of tankers, accidents on gas pipelines, power stations, in case of transportation by road and rail. The process of transporting pellets is much easier and safer. It is not difficult to collect them after an accident, and what remains will not cause harm to the environment, because they do not use chemical compounds during their production.

7.1.2. Feedstock for the Production of Solid Biofuels

Agricultural biomass used as fuel has a number of characteristics that distinguish it from traditional heating energy sources. Some of the characteristics of solid biofuel, especially external (density, particle size, surface specificity), through grinding and compacting can be changed, but its main fuel and technological characteristics are generally considered as constant.

Biomass as a primary energy source is used in an unchanged form for direct combustion or preliminarily subjected to chemical processing.

The quality of biofuels is determined by three phases: Phase I – cultivation; Phase II – harvesting and processing; Phase III – energy use. Impacts of phase I include the choice of the type and variety of the cultivated plant, the state of its maturity, soil and climatic conditions, technology and technical means of cultivation, the availability of fertilizers, plant protection products, and the state of atmospheric air (in particular, its pollution). In Phase II, the influence is determined by the nature of the individual pre-treatment operations used for biomass (wood chips, straw sticks, bales, rolls, pellets or briquettes), which ultimately determines the physical and chemical characteristics of biofuels. Phase III is a complex interaction between the properties of biofuel and the combustion device.

Now, the most common feedstock for the production of solid biofuel are:

– energy fast-growing trees (willow, poplar);
– sawdust of hard and soft species of trees;
– husks of sunflower, buckwheat, flax;
– straw;
– grapevine.

An important fuel and technological characteristic of biomass, which is used as a solid fuel, is its calorific value, which depends on many factors: the genetic characteristics of energy plants, environmental influences, storage conditions, humidity, etc. The calorific value of agricultural energy feedstock with 20% of absolute humidity are given in Table 7.2.

Table 7.2

Calorific Value of Agricultural Energy Feedstock

Feedstock	Calorific value, MJ/kg
Straw of cereals	10.5
Stalks of corn	12.5
Branches of fruit trees	10.5
Stalks of sunflower	12.5
Grapevine	14.2

The calorific value of biofuel (kJ/kg) decreases in proportion to the increase in moisture content in the biomass.

The quantitative reflection of the burning process of plant biofuels causes a number of difficulties associated with its heterogeneity. There are data on the release of heat during the oxidation of combustible chemical elements, which are brought to a temperature of 250°C. But under real conditions, the heat of combustion of the fuel is lower, as part of the heat is spent on heating the fuel and its incombustible components to the combustion temperature.

It should also be taken into account that the temperature of the fuel varies and is related to the heat sink conditions and the air supply during combustion.

When studying the characteristics of burning straw, it was found that it contains a large number of volatile compounds (CO, H, CH, etc.), which are released in significant volumes at a combustion temperature of 250 to 300°C. Their afterburning needs a significant air excess, which leads to the formation of a large amount of smoke. This phenomenon is usually called gasification, so without proper preparation of straw and the organization of the combustion process, the efficiency of heat engineering equipment is reduced.

The formula of D.I. Mendeleyev received the greatest application in the practice of combustion, it reflects the relationship between the composition of solid fuel and its calorific value. The application of this formula gives an approximate result, therefore the determination of the energy value of the fuel or the heat of combustion is carried out in the laboratory by direct measurement using a calorimetric bomb. In this device, the sample is burned without losing the constituent fuel in an oxygen-sealed, sealed metal container. It is known that the heat of combustion of cereal straw with a moisture content of 15% varies over a wide range and is 13.6-15.6 MJ/kg, but in most cases the heat of combustion of straw is shown without taking into account humidity and combustion conditions, which makes it difficult to assess the energy potential.

On the basis of generalized data, empirical relationships are obtained for determining the heat of combustion of various types of straw. These dependencies are advisable to use in the technical and economic assessment of the efficiency of burning specific types of straw. In the calculations, performed to justify the use of plant biomass for a particular region or the state as a whole, the heat of combustion of straw should be determined by the expression, taking into account the significance of the volumes of straw of a particular type. For example, it is known that the main volumes in Ukraine belongs to wheat straw (from 40 to 60%), barley (from 20 to 30%), rye (from 3 to 6%) and legumes (from 2 to 8%). In recent years, the share of rape straw has increased (4-6%).

Owing to the large content of oxygen in agricultural biofuel, the need for air and the amount of generated smoke during combustion are less than when burning various types of coal (Table 7.3). The moisture content of the fuel is unfavorable not only from the point of view of the calorific value of the material. With increasing humidity, the amount of water vapor increases, as a result of its condensation processes, creates problems with the removal of smoke.

Table 7.3

The Need for Air and Ash Content in Various Solid Fuel Materials

Fuel	Specific requirement for air during combustion, m3/kg	Ash content,%
straw	5.65	4-10
wood	7.63	1-2
charcoal	10.52	0.8
brown coal	8.33	0.8
coal	10.85	0.08

Wood as energy raw material consist of wood waste from forest production and wood processing industry, trimming branches and tree crowns, and from perennial trees which are grown in the so-called energy forests. Wood is a chemically heterogeneous material. It consists of cellulose, hemicellulose and lignin. Lignification of cell walls in coniferous trees is approximately 30%, deciduous trees – 20%. Wood is used in various forms – as logs, branches, chips, sawdust and even wood dust. Sawdust and dust of wood, as a rule, are used in the form of briquettes. Just as for straw, for various types of wood, the most important thermophysical parameters are the energy value, which depends on its chemical composition, related to the type of wood and moisture.

The energy value of wood with a moisture content of 50-60% is 6-8 GJ/t, and after drying to an air-dry state (humidity 10-20%) it doubles (14-16 GJ/t).

Wood is harvested at various stages of its processing and is therefore differentiated for both the assortment and the suitability for burning. The assortment of tree for heating needs is the following: 70% – large logs, 20% – small logs, 10-15% – stumps, hemp and bark. Waste from wood processing and paper industry are tens of millions of cubic meters. Wood for heating is a shredded to varying degrees of wood from parts of a stump, cut ends of a root, and also branches. The wood for burning is usually divided into parts 0.20-0.40 m in length, with a thick of 0.06-0.10 m, which makes it possible to burn in most furnaces. The notion of a notch means pieces of wood 5-50 mm in length, differentiated form of fiber, particles, cod and others.

The degree of grinding wood essentially pours out the technological productivity of grinders, so it is desirable to normalize its value. The wood for heating can also be used in the form of briquettes with a length of 0.10-0.25 m, rectangular or round in section (Width = 0,06-0,12 m) and bundles, which are usually cylindrical (5-40 mm in length and diameter of 8-12 mm). Both briquettes and bunches are formed mainly from sawdust and chips on briquette presses and high pressure granulators with the addition of binder. Briquettes and granules should have a moisture content of 8-10%, and the amount of ash produced during their combustion should not exceed 1% (without the tendency to its conglomeration). In some enterprises, dry wood pieces of wood are ground (<5%) in mills – to a state of dust with a particle size of less than 0.8-1.0 mm, which makes it possible to burn them in special boilers. The balance of energy costs in the production and burning of wood briquettes, pellets and dust is not always positive, so they are produced mainly by enterprises that have an "excess" of cheap feedstock, which is treated as waste (cellulose enterprises, etc).

The suitability of wood for burning depends on the type of wood, its humidity, and also on the content of mineral and chemical constituents. From the ecological point of view, the last two elements are dangerous, since they can be a source of emission into the environment of very toxic substances or heavy metals during combustion. Therefore, in the near future, waste from wood processing will be used as energy feedstock, first of all, in places of its origin and considerable concentration (at the enterprises for the production of tree-like plates, plywood) briquettes and granules.

Growing trees and bushes is determined by the concept of energy forests. It began with an attempt to use degraded, eroded soils and lands derived from agricultural use. These soils are characterized, as a rule, by low availability for agriculture, they contain a small amount of humus and a large amount of nitrogen and phosphorus, they mostly have an unsatisfactory air-water regime. In such an environment, only a small number of plants are capable of vegetation and a rapid increase in biomass. In European practice, in particular in the Scandinavian countries, the common willow and poplar are often used. The advantages of these two types of trees include a small load on the environment in the process of their cultivation, biomass production in the winter period and industrial technology of energy production. Both types of wood have greater mass increase per time unit compared to the increase in the mass of natural forests. It should be noted that due to the high cost, the final decision on the issue of obtaining energy raw materials from industrial forests remains open. These technologies are still in the phase of experiments to improve them.

Poplar cultivars grown for the production of biomass in energy forests are a combination of North American and black European poplar. Poplar plantations are laid on soils with a pH of 5.0-7.5 with an appropriate balance of water and fertilizers, while the amount of precipitation during the vegetation period should not be less than 300-350 mm. Field preparation consists of plowing at a standard depth of 0.25-0.30 m. Saplings of about 0.25 m long are planted manually, which requires up to 7-8 people-days per hectare, or mechanized. The seedlings are obtained in 2-4 years from annual shoots, planting them at a rate of 16 thousand pieces per hectare. When planting a plantation, it is planned that in 6-8 years the density of plantations does not exceed 1700-2000 trees per hectare. In the first year, it is necessary to pay attention to the possibility of clogging plantations, which must be eliminated mechanically or chemically. Some data indicate the expediency of applying nitrogen fertilizer in the amount of 50-60 kg/ha in the first 2-3 years of cultivation of trees. The poplar plantation gives an average annual increase in the dry weight of the tree in the range of 5-6 tons during the first 4-6 years of use, and from the 5th to the 9th year this increase is 12-20 tons of dry mass/ha per year (Figure 1.5). On average, over a 6-8-year growth period, the increment ranges from 12 to 14 tons of dry mass/ha per year.

During the cutting down (usually in March), the moisture content in the mass of wood with a diameter of about 80 mm is 45-55%, and the bulk mass of the tree, crushed into pieces smaller than 50 mm, is about 160 kg/m^3.

The productivity of special harvesters for harvesting green mass with special heavy adapters reaches 23 tons/h. After drying to a humidity of 9-12%, the bulk weight is about 100 kg/m^3, and the energy value is 17.5 MJ/kg. On plantations 6-8 years after cutting, trees reach a height of 18-20 m, and for harvesting the same machines as for natural forests can be used.

Willow bushes tolerate low temperatures well, but are afraid of frosts in early spring and early autumn, when damage to upper shoots is possible. Selecting clones for seedlings, it is necessary to take into account soil conditions and planting purposes. Plantations planted near the forest are seriously endangered by diseases and pests.

Willow is considered a plant suitable for cleaning soils from heavy metals, radionuclides and toxic compounds due to their processing into biomass. The root system of the willow penetrates into the soil to a depth of several meters, and the high coefficient of transpiration of rainwater limits the leaching of harmful substances into the groundwater. The preparation of the field consists in deep plowing in autumn, and some researchers recommend deep loosening of soil before plowing in order to create better conditions for the development of the root system of the willow.

If the biomass has a form an easy to use (for example wood), it can be burned directly in furnaces or boilers to produce heat or steam.

The main types of biomass, used as solid biofuel for direct combustion, include wood together with feedstockfrom energy plants – such as willow, straw and glade with different kinds of plantings. Burning of wood and straw in furnaces is preceded by collection, and if necessary drying and storage of collected raw materials.

An important characteristic of biomass used as a solid biofuel is its density. Of course, dry biological materials have 3-4 times lower density than coal. The delivery and processing of such materials is laborious and expensive, especially if the disposal site is remote from sources of biomass production. Therefore, an important factor in the quality of solid biofuels is the technology for preparing biomass for combustion. It determines the design and technological execution of heat engineering equipment, significantly affects the economic performance of its operation

If the biomass has a form that is inconvenient for use form (sawdust, chips, grass, urban wood waste, agricultural waste), it must be compacted (compressed).

The process of production of fuel briquettes and pellets from biomass includes the following technological operations:

1. Grinding of raw materials to fine fractions.
2. Drying raw materials to a moisture level of not more than 12%.
3. Pressing.
4. Cooling.

Granulated biofuel from biomass is one of the most suitable for the automated combustion process. It is stored in special bins, and then transported directly to the power plant. The whole process of moving granules can be automated.

Straw is also burned in the form of briquettes (Figure 7.1), pressed in round rolls or packs of rectangular cross-section or in a crushed form. At the same time, it is most effective to harvest straw with the use of pressing into rolls or bales. The use of fixing the shape of the rolls of mesh facilitates their energy use.

Figure 7.1. Fuel Briquettes from Biomass

Received briquettes do not contain sticky substances, except for one natural – lignin in the cells of plant waste.

The calorific value of fuel briquettes is higher than coal. So if a cubic meter of sawdust or chips with a humidity of 15% during combustion releases 500-600 thousand Kcal, then the same volume of fuel briquettes allocates from 4 to 5 million Kcal.

Biofuel pellets and briquettes are easy to transport, they do not absorb moisture, do not rot and do not lose their fuel properties during storage, and are most suitable for mechanized loading in a power plant.

7.1.3. Equipment for the Use of Solid Biofuels

Taking into account the features of biomass burning technologies, all solid fuel boilers can be conditionally divided into the following groups:

1. Traditional solid fuel boilers.
2. Solid fuel boilers with pyrolysis burning of wood (gas-generating).
3. Universal (multi-fuel) boilers, which can work not only on solid fuel, but also on gas, liquid fuel, electricity.
4. Solid fuel boilers of long burning.
5. Automatic boilers.

The main technologies for the thermal processing of solid biofuel (plant biomass and wood) are direct combustion, gasification and pyrolysis. Burning biomass is the easiest way to get energy. In many cases, this method is considered the most economical. In the chemical sense of combustion, all organic materials are converted to carbon dioxide and water in the presence of oxygen (usually atmospheric). The very large heterogeneity of biomass, in terms of chemical composition and physical properties, causes certain difficulties both in the combustion process and in the emission of components that are by-products of the process.

The results of the development of the problems of the energy use of biofuels from plant biomass are embodied in the creation of a new generation of heating devices with an efficiency of between 80 and 90%. So, "Brovarsky plant of municipal equipment" produces a standard series of multi-fuel hot-water boilers that operate on firewood, sawdust, fuel briquettes and peat, and also use coal as a fuel. These efficient boilers are designed for supplying heat to household, municipal and industrial facilities.

In typical constructive-technological solutions of automatic boilers, the function of metering devices is performed by screw conveyors, guided by a given program (Figure 7.2). The efficient use of boilers on solid biofuels is due to the development of modern technologies for the preparation of raw materials, systems for automatic control of the combustion process and special (ceramic) materials of the combustion chambers.

Automatic water heating boilers are designed for heating residential houses, villas and other objects with a thermal load of 25 and 50 kW. Due to the large volume of the furnace, electronic control with a vacuum and thermostat, and the pump, and the boilers are operated in an automatic mode. They are designed to burn fuel pellets from wood and plant biomass. The demand for biofuel at nominal capacity is 7.2 and 9.7 kg per hour, respectively. With a minimum loading of these boilers, 1.5 and 2.3 kg of pellets per hour are sufficient. Pyrolysis boilers are designed for burning wood with a diameter of 80-150 mm with humidity up to 20% and fuel briquettes from biomass, and up to 10% of chips or small wood waste can be added to the charging chamber. High efficiency during the heating period allows to get additionally installed with pyrolysis boilers storage tanks that can continue the work of the heating system within 1-3 days after the last loading of biofuel. The boiler needs the volume of the storage tank be up to 1500 liters.

Figure 7.2. General View of The Automatic Boiler Operating on Fuel Granules

There is burning wood that is released from the wood due to the high temperature in the combustion chamber in solid fuel boilers with pyrolysis burning of wood (gas-fired boilers), unlike the traditional hard-burning fires. During such combustion, there is no soot, and ash formation is minimized. Boilers with pyrolysis wood combustion (gas-fired boilers) have a high efficiency (up to 85%).

Solid-fuel long-life boilers are devices with burning of one fuel loading rate can last from 7 to 34 hours. In the design of solid-fueled long-life boilers, a step-by-step method for burning solid fuel is used. Such combustion in the boiler is provided by the air distributor, fed to a certain part of the furnace of the boiler and stimulates the burning of a certain layer of fuel. Then the distributor is displaced, then the next layer of fuel is burnt. Solid fuel boilers of long burning as fuel can use wood, briquettes from sawdust, straw and peat.

Universal boilers have a combustion chamber for solid fuel, as well as the possibility of installing hinged burners for the use of gas or diesel fuel. Also there are universal boilers that have a built-in heating element (tubular electric heater) for the operation of a heating system for electricity.

The undeniable advantage of solid fuel boilers is the reduction of costs compared to traditional heating systems. For example, consider a pilot project for switching to alternative heating in Vinnytsia National Agrarian University (VNAU).

The total heated area of the academic buildings is 17772 m^2. The heating season of 2013/14 in the VNAU lasted from October 15 to April 15 (6 months). In total, 812 Gcal of energy was consumed for heating. The cost of 1 Gcal of energy in 2013 was 940 UAH. Thus, the cost of traditional heating in 2013 in the VNAU was 763,503 thousand UAH. The cost of 1 Gcal of energy as of November 1, 2014 was 1347.16 UAH.

Thus, heating costs for 2014/15 years increased by 330,390 thousand UAH and reached 1094,000 UAH.

In 2014, a universal solid fuel boiler of the KRIGER brand was installed on the basis of the Vinnytsia National Agrarian University. It has a capacity of 0.73 Gcal/h.

The peculiarity of this boiler is that it can work on any kind of fuel. The fuel consumption depends on the raw materials (Table 7.4.)

Table 7.4

Fuel Consumption, kg/day

Firewood	3 026	3026
Straw	2 147	2147
Briquettes	1 383	1383
Charcoal anthracite	1 023	1023
Natural gas, m3	622	622

Expenses for heating of educational buildings for the use of various types of fuel are given in Table. 7.5.

Table 7.5

The Cost of Heating the Class-Rooms When Using a Solid Fuel Boiler and Various Types of Feedstock

Indicators	Bri-quettes	Firewood	Fuel Coal	Straw	Natu-ral gas (2013)	Natu-ral gas (2014)
The cost of 1 t	2000	900	3200	1000	4550	6400
The required amount for heating, t	249	544,8	184,3	386,5	112,000 m^3	112,000 m^3
Costs for raw materials, UAH	498 000	476 745	589 836	386 500	509 600	716 800
Savings in comparison with the costs of the traditional boiler house (minus the cost of maintenance of the boiler, amount to approximately 190 thousand UAH)						
		409 000	427 255	317 164	517 500	394 400

The average lifetime of this boiler is 20 years. The cost of the boiler of the brand KRIGER equaled 335 thousand UAH. By using bio feedstock for heating the University, the costs of installing a solid fuel boiler will pay off in a year.

7.1.4. Potential for Solid Biomass in Ukraine

Ukraine has sufficient energy potential of almost all types of biomass and the necessary scientific, technical and industrial base for the development of this energy sector.

The main constituents of the biomass potential are straw and other agricultural wastes (stems, cobs, husks, and wood waste). In Ukraine, it is harvested up to 15 million m^3 of wood. Waste processing consist of:

12% – from the volume of logging;
35% – from the volume of sawmilling;
31% – in the production of furniture,
31% – in the construction of housing.

For Ukraine, first of all, it is necessary to use the available waste of solid biomass (wood, straw), since the cultivation and use of energy crops (willow, poplar, miscanthus) is the business of the next 5-10 years.

Available stocks of feedstock for the production of solid biofuels can provide more than 10% of Ukraine's total demand for primary energy.

The Ukrainian branch of solid biofuel is actively developing in recent years due to the continuous growth of demand for alternative fuels and, consequently, the prices for it in the world and European markets. According to the Ukrainian Biofuel Portal, only in the wood pellets production sector in Ukraine there was an almost twofold increase in the number of producers in the year 2012, which reached 105 by the end of the year. A similar growth is observed among enterprises that produce pellets from husk sunflower and straw, as well as solid fuel pellets, wood briquettes. Until the end of 2012, Ukrainian companies produced about 1.5 mln tons of various types of fuel briquettes and pellets, and the export of solid biofuel from our country provides up to 10% of the total EU demand for this product.

The bulk of the solid fuel produced in Ukraine – up to 90% in 2012 – used for export. The main consumer of Ukrainian pellets from wood waste, husks of sunflower and straw for many years is Poland, which buys relatively cheap Ukrainian pellets for the needs of TPPs.

Despite the fact that European Union countries have begun protectionist measures to protect their markets, and the requirements to the quality of solid biofuels have increased, the export orientation of Ukrainian producers of solid biofuels has changed somewhat. Ukrainian producers of solid biofuels began to reorient to sell their products within the country.

According to the results of 2012, 13,330 tons of solid biofuel (pellets and briquettes from wood materials, husks of sunflower and straw in Ukraine were produced. In 2013, the production was 14.5 million tons, the forecast for 2014 was 1.5 mln tons. In the period 2013-2014, in the Ukrainian domestic market, the demand for solid biofuel grew 2 times – up to 570 thousand tons, from 20% to 40% of the total volume of products produced by Ukrainian enterprises.

Faced with the deterioration of Ukraine's energy dependence on imported energy resources and the increase in their cost, many Ukrainian producers reoriented the supply of solid biofuels to the domestic market. Also, thanks to the action in Ukraine of a "green" tariff for electricity generated from biomass, a segment of electricity production from biomass began to develop in the country. In particular, the total installed capacity of biofuel boiler in houses in Ukraine amounted to 90 MW. Also, many industrial enterprises, in particular oil extraction plants, brick and cement manufacturers, are actively introducing technologies for substitution of natural gas with alternative fuels. In particular, following the results of 2013, due to the use of biofuel, these enterprises reduced gas consumption by 220 million m^3.

Basic definitions and concepts. *Solid biofuels. Wood. Firewood. Peat. Sawdust. Cod. Straw. Vine. Pellets. Briquettes. Granules. Calorific value. Solid fuel boilers. Heat generation.*

Test questions and tasks

1. What is solid biofuel?
2. Describe the history of the development of solid biofuels.
3. Name the largest producers and consumers of solid biofuels in the world.
4. What are the environmental benefits of using solid biofuels?
5. What is the feedstock for solid biofuel production?
6. What is the process for the production of fuel briquettes and pellets?
7. Describe the potential of solid biomass in Ukraine.
8. Describe the current state of production of solid biofuel in Ukraine.
9. Analyze equipment for the use of solid biofuels.
10. Describe the perspectives of the solid biofuel sector in Ukraine.

PART 2. SECOND GENERATION BIOFUELS

Key issues

7.2.1 Characteristics of Second Generation Biofuels

Second generation biofuel technologies are able to manufacture biofuels from inedible biomass and avoid conversion of food into fuel.

Biofuel of the second generation is produced with the help of the following ways of transformation of the biomass:

- Biochemical;
- Thermochemical.

Biochemical transformation is carried out on the basis of the addition of enzymes to cellulose-containing biomass and its transformation into second-generation bioethanol.

Biochemical Conversion

A number of biological and chemical processes are being adapted for the production of biofuel from second generation feedstock. Fermentation with unique or genetically modified bacteria is particularly popular for second generation feedstock like landfill gas and municipal waste.

Thermochemical Conversion

The first thermochemical route is known as gasification. Gasification is not a new technology and has been used extensively on conventional fossil fuels for a number of years. Second generation gasification technologies have been slightly altered to accommodate the differences in biomass stock. Through gasification, carbon-based materials are converted to carbon monoxide, hydrogen, and carbon dioxide. This process is different from combustion in that oxygen is limited. The gas that result is referred to as synthesis gas or syngas. Syngas is then used to produce energy or heat. Wood, black liquor, brown liquor, and other feedstock are used in this process.

The second thermochemical route is known as pyrolysis. Pyrolysis also has a long history of use with fossil fuels. Pyrolysis is carried out in the absence of oxygen and often in the presence of an inert gas like halogen. The fuel is generally converted into two products: tars and char. Wood and a number of other energy crops can be used as feedstock to produce bio-oil through pyrolysis.

A third thermochemical reaction, called torrefaction, is very similar to pyrolysis, but is carried out at lower temperatures. The process tends to yield better fuels for further use in gasification or combustion. Torrefaction is often used to convert biomass feedstock into a form that is more easily transported and stored.

Henri Braconnot discovered in 1832 that nitric acid, when combined with starch or wood fibers, would produce a lightweight combustible explosive material, which he named xyloidine. A few years later in 1838, another French chemist, Théophile-Jules Pelouze (teacher of Ascanio Sobrero and Alfred Nobel), treated paper and cardboard in the same way. Jean-Baptiste Dumas obtained a similar material, which he called nitramidine. These substances were highly unstable and were not practical explosives. The Germans first commercialized cellulosic ethanol production from wood in 1898. The technology was commercialized in the U.S. in 1910, when Standard Alcohol Company built a cellulosic ethanol plant in South Carolina to convert lumber mill waste into ethanol. Standard Alcohol later built a second plant in Louisiana. Each plant was capable of producing over 5,000 gallons of ethanol per day from wood waste, and both were in production for several years before being idled for economic reason.

Research in the production and consumption of second-generation biofuels is being conducted in the US, Brazil and the EU. The experimental fossils for the production of second-generation biofuels have been built in Australia, Canada, China, Denmark, Germany, Japan, Norway, Spain, Sweden, the United Kingdom and the United States, Only in the United States, there are 12 plants that work for the production of ethanol from cellulose.

Beta Renewables opened its first plant in Italy in the final quarter of last year and sees 2018 as a turning point for the industry as demand surges and more production comes online. Crescentino in figures: value of the investment: 150 million Euro; production: 40,000 tons of bioethanol/year (potential of 60,000 t/a); bioethanol is distributed in Europe, blended with petrol; area: 150,000 square meters; biomass used: 270,000 t/y (at maximum potential) 13MW elec-tricity production, entirely produced using lignin, the plant is totally self-suffi-cient with regards to its energy consumption; water recycling: 100%; employees: approx. 100.

To build the plant the following equipment was required: 370 machines; 1,500 tons of steel; 1,400 tons of pipes and valves; 30,000 tons of concrete; 18 km of underground pipes.

7.2.2 Feedstock for Second Generation Biofuels

The first generation biofuels refer to the fuels that have been derived from sources like starch, sugar, animal fats and vegetable oil. The oil is obtained using the conventional techniques of production. Second generation biofuels use biomass, meaning any plant-derived material, as a feedstock – much like first generation biofuels. But unlike first generation biofuels this biomass can be derived from non-edible sources and/or waste matter. By broadening the scope for feedstock supply, second generation biofuels could help resolve issues relating to the impact of biofuel production on food production.

The second generation feedstock are biomass, where the carbohydrates, which are potentially capable of being converted to alcohol, are in a technologically accessible state (for example, in cellulose) or are not fermented into ethanol by traditional yeast (pentoses).

Cellulose (cellulose) is a linear high-molecular polysaccharide, built from a large number of bound 6-carbon molecules of sugars – glucose and its isomers. It has a crystalline structure, they do not dissolve at room temperature either in water, dilute acids, or in alkalis. Cellulose is the main structural component of plant cells and can be isolated in the form of fibers. The number of glucose molecules bound in one cellulose molecule depends on the plant species and can reach 27,000. Cellulose at room temperature is hydrolyzed by concentrated acids or enzymes to form glucose.

Hemicellulose is a heterogeneous polymer containing both 6- and 5-carbon sugars. Depending on the plant species, its content can be from 11 to 37% of dry biomass. It does not have a crystalline structure, is characterized by a shorter molecular chain compared with cellulose, molecular chains, and is therefore more accessible for hydrolysis.

When hemicellulose is hydrolyzed, pentoses – xylose, arabinose, are not fermented with alcoholic yeast, as well as hexoses: mannose, glucose, galactose and a small amount of rhamnose, gluconic and galactonic acids are produced.

The main characteristic feature of second generation biofuels is that they are made from non-food biomass. Feedstock for the production of second generation biofuels can be:

- cultures grown directly for the production of biofuels (energy fast-growing willow, poplar, miscanthus, switchgrass, grass);
- waste from agriculture (straw, corncobs and corn stalks, husks, waste oil);
- waste wood industry;
- municipal solid waste.

Different amounts of fermented sugars can be received from the various types of lignocellulosic feedstock. For example, poplar wood contains: cellulose – 49%; hemicellulose – 20%; lignin – 18%. The content (%) of these components in the agricultural residues are shown in Table. 7.6.

Table 7.6

The Content of Components in the Waste of Agricultural Production, %

Raw material	Cellulose	Hemicellulose	Lignin
Stalks of corn	36.4	22.6	16.6
Wheat straw	38.2	24.7	20.4
Rice straw	34.2	24.5	18.4

Lignocellulose is much more complex structure compared to starch or especially sucrose. This, in fact, is due to the fact that today there is no cost-effective technology for the conversion of lignocellulose to ethanol.

Let us consider the structure of lignocellulose in more detail. The average con-tent in cellulose of lignocellulose is 45%, hemicellulose 30% and lignin – 25%. These figures are very average. The content of cellulose can range from 15% in leaves or 25% in the shell of nuts to 95% in hairs of cottonseed, 85-99% in paper, hemicellulose from zero in paper and 5-20% in hairs of cotton seeds to 50% in wheat straw, 85% in leaves, and lignin – from zero in paper and leaves to 40% in the shell of nuts. Cellulose and hemicelluloses are sugar poly-mers, while lignin is an aromatic heteropolymer. Only products of hydrolysis of polymers of sugars (cellulose and hemicellulose) can be used as substrates for biotechnological conversion to ethanol.

Despite the fact that the biomass containing cellulose – straw, stalks, wood waste, is very cheap, its transportation and transformation is suitable for fermentation by yeast, the product requires considerable energy consumption, the use of expensive enzyme preparations and special microorganism cultures.

7.2.3 Ways to Produce Second Generation Biofuels

Bioethanol from cellulose by the method of hydrolysis and fermentation by means of enzymes

All plants contain lignin, hemicellulose and cellulose. These are complex carbohydrates (sugar-based molecules). The feedstock for the production of biofuel of the second generation can be any cellulose raw materials. Bioethanol from lignocellulose is produced by releasing sugar molecules from cellulose by using enzymes, heating by steam or other kinds of pretreatment. Cellulose after its splitting into mono- and oligosaccharides is easily biologically transformed into bioethanol or other alcohols suitable for use as liquid fuel. Further, these sugars can be fermented for the production of bioethanol in the same way as for first-generation bioethanol. The by-product of this process is lignin. Lignin can be burned as a carbon neutral fuel for heat and power generation. Chemical pretreatment of feedstock is necessary for the preliminary hydrolysis of hemicellulose so that it can be more efficiently converted into sugar. The method of production of bioethanol by means of hydrolysis includes the following steps:

1. Preliminary processing of feedstock.
2. Hydrolysis of cellulose to break the molecules of lignin into sugars.
3. Separation – separation of sugars from lignin.
4. Fermentation of sugars.
5. Distillation.
6. Dehydration.

Preliminary treatment is needed to partially destroy microfibrils of cellulose, reduce the degree of its crystallization and polymerization, removal of hemicellulose, destruction of the cellulose complex with lignin, and modification of the structure of lignin, an increase in the surface available for the action of hydrolytic enzymes, and also for the removal of lignin (delignification). Pretreatment includes mechanical grinding of plant biomass, treatment with superheated steam or the action of acids or alkalis for delignification. As a result of pretreatment, not only delignification is achieved, but also partial hydrolysis of hemicellulose and cellulose.

The hydrolysis of cellulose and hemicellulose to monosaccharides can take place with the participation of acids or enzymes. Acidic hydrolysis can be carried out with dilute sulfuric acid or concentrated sulfuric or hydrochloric acids. Hydrolysis with dilute acid is the classical and cheapest method, but it has a number of disadvantages, in particular, the formation of large amounts of toxic by-products that inhibit the growth and fermentation of microorganisms (furfural and methylfurfural, acetic and formic acids, phenols) whose detoxification is sufficiently valuable. An important approach may be the selection of mutants of microorganisms resistant to these inhibitors. Hydrolysis by concentrated acids forms less toxic side products, however this process is more expensive and creates serious environmental problems.

Biomass gasification

Gasification is the thermal conversion of biomass into combustible gas, volatiles and ash in a closed reactor in the presence of an external oxidizer (oxygen, carbon dioxide). Gasification is carried out in two stages. In the first stage, volatile components (hydrocarbon gases, hydrogen, carbon monoxide, carbon dioxide, tar and water vapor) evaporate at temperatures below 600°C using a set of complex reactions. This stage of the technological process passes without the use of oxygen.

Carbon and ash are by-products of the process, that do not evaporate. In the second stage, carbon is gasified by reacting with oxygen, steam and hydrogen. As a result, the resulting gas is called "syngas".

As a result of gasification of biomass, a liquid fuel type can be obtained. In the world, such a process of biomass conversion was called "BTL" (biomass to liquid – biomass into solid fuel). This type of biofuel is produced from non-food feedstock (straw, wood waste, plant stems) using a three-stage gasification system.

At the first stage, the biomass is heated in the presence of oxygen to 400-500°C, divided into bio-coke and rich in resinous substances. In the second stage, this gas in a special combustion chamber at a temperature above 1400°C is enriched with oxygen. In the third stage, the gas and ground bio-coke are mixed and converted into a synthetic gas that can be used to produce electricity and heat, or become a liquid fuel by the Fischer-Tropsch process.

Pyrolysis

Pyrolysis is the decomposition of organic compounds under the action of high temperatures (from 450°C) in the absence of oxygen, resulting in the formation of a liquid (bio-oil), gases and coal. The yield of these substances depends on the feedstock, temperature and duration of the reaction. Pyrolysis differs from other high-temperature processes, such as combustion and hydrolysis, in that it usually does not involve a reaction with oxygen, water or any other reagent. Before subjecting the pyrolysis biomass, it is crushed to a size of less than 1 mm in order to accelerate the reaction process.

The particles are captured by an inert gas flow, which ensures a high rate of material transfer to the pyrolysis reactor. Inside the reactor, the particles quickly heat up at a temperature of 450°C and transform into a condensed vapor, uncondensable gases and hard coal.

These products are transported from the reactor above the condensation point of the pyrolysis vapor, where the coal is removed. The vapors and gases are transported to a tank for direct cooling, where the liquid pyrolysis stream cools and condenses steam. Gases do not condense, which include combustible CO, H_2 and CH_4, are burned to provide energy to the pyrolysis reactor.

Torrefaction

Torrefaction is the thermochemical treatment of biomass in the absence of oxygen at a temperature of 250 to 300°C. During the process of torrefaction, the water remaining in the biomass evaporates. In addition, the content of hemicellulose in biomass is reduced.

The final product is a dry substance of brownish-black color, from which solid biofuel in the form of pellets or briquettes, the so-called bio-coal, is produced.

Basic definitions and concepts. *Biofuel of the second generation. Cellulose. Lignocellulose. Biochemical transformation. Thermochemical conversion. Miscanthus. Svitchgras. Hydrolysis. Fermentation. Enzymes. Gasification. Pyrolysis. Torrefaction.*

Test questions and tasks

1. Give the definition of second-generation biofuel.
2. What is the feedstock for the production of second generation biofuels?
3. What is the main difference between the first and second generation biofuels?
4. What are the main methods of production of second generation biofuel?
5. Describe the process of production of bioethanol from cellulose by hydrolysis and fermentation using enzymes.
6. How is biomass converted into liquid fuel by gasification?
7. What is pyrolysis?
8. What is the peculiarity of the process of recovery?
9. Which countries are engaged in research in the field of biofuel production of the second generation?
10. What are the main obstacles to the introduction of mass production of second generation biofuels?

CHAPTER 8
SOLAR ENERGY

Key issues

8.1. Solar Energy. Technical and Economic Aspects
8.2. Basics of Using Solar Energy
8.3. State and Prospects of Development of Solar Energy in Ukraine

8.1. Solar Energy. Technical and Economic Aspects

Solar energy is one of the most significant sources of energy on our planet. The solar radiation power is about 1 kW per 1 m^2 of the earth's surface, and about 10 billion kW per the surface area of 100x100 km. According to scientists, the total world reserves of solar energy are 86 trillion t of s.f. in a year.

Each second nuclear reaction converts approximately 700 million tons of hydrogen to helium, and a large amount of energy is released. As can be seen from Table. 7.6, the radiant energy of the sun has the greatest overall potential compared to all other world reserves of alternative energy sources.

The energy of any kind of organic fuel is solar energy, accumulated in the form of a chemical. Solar energy is concentrated mainly in carbohydrates – glucose, sugar, starch and cellulose. When fuel is burned, the accumulated solar energy is released. However, this process is environmentally harmful – it poisons the atmosphere with toxic substances.

Pollution of the environment, especially traditional energy sources, has reached unprecedented levels in recent decades. If such negative trends continue to worsen the Earth's ecology in 20-30 years, the emission of carbon dioxide in the biosphere of the planet will reach 43 billion tons, sulfur dioxide – 355 million tons, the amount of spoiled water will be 15 trillion 270 billion tons.

Solar radiation is an inexhaustible source of clean energy.

Structure of the Sun

The Sun is the central and massive body of the solar system, it is, in fact, a hydrogen bomb, a thermonuclear reactor in which helium atoms are synthesized from hydrogen atoms. With this transformation, energy is released in the form of radiation of various kinds, which forms a continuous spectrum with waves of different lengths.

Table 8.1

World Reserves of Alternative Energy Sources

Alternative energy sources	Total potential, billion tons of equivalent fuel/year	Technical potential, billion tons of standard fuel/year	Economic potential, billion tons of equivalent fuel/year
Radiant energy of the Sun	86 000	5	1
Thermal energy of the seas and oceans	7500	1	0-1
wind energy	860	5	1
Hydropower, including energy of:	6.065	3	1.52
Watercourses	3	2.91	1.5
Waves	3	0.05	0.01
Tides	0.065	0.04	0.01
Biomass, total, including:	40	2.55	2.0
Forests	15	1.5	1.5
Plants	10	1.0	0.5
Seaweed	15	0.05	0
Geothermal energy	16	0.4	0.2
Total	94422.065	16.95	5.72 – 6.72

The mass of the Sun is *330 thousand times* greater than *the mass of the Earth*. Under the influence of its own gravity, its substance in the center is under enormous pressure and has such a high temperature that nuclear reactions occur there. They are accompanied by the release of energy, the Sun continuously radiates into the surrounding space. A relatively small core makes up most of the mass of the Sun and almost completely determines its luminosity.

Energy and solar matter are transferred to the surface of the Sun by convection.

Photons with the speed of light appear in the nucleus. Then they move relatively slowly to the surface of the Sun, as their trajectory passes through the solar material, which to some extent slows down this movement. The sun is so dense that photons spend about 1 million years to reach its surface.

8.2. Basics of Using Solar Energy

Direct use of solar energy is divided into thermal, photographic and thermoelectric conversion, that is, to receive thermal or electrical energy under the influence of solar radiation at various special reception devices – solar collectors (SC) or photoconverters.

Thermal use of solar energy. The following basic quantities are used to characterize solar radiation and its interaction with matter.

The radiation flux is the energy emitted by the electromagnetic waves in one second through a unit of an arbitrary surface (J/sec = W).

Density of the radiation flux (energy illumination) is the ratio of the radiation flux to the surface area is irradiated. The density of the radiation flux from the sun, falling on a square perpendicular to it outside the earth's atmosphere, is also called the solar constant.

The absorption coefficient is the ratio of the radiation flux absorbed by the surface of the body to the flux of radiation incident on this surface in the same spectral interval. It depends on the frequency (wavelength) of radiation, the nature and temperature of the body. The body for which the absorption coefficient is unity, absorbs all the radiation, falls on it, and is called an absolutely black body.

The reflectivity of a body is the ratio of the radiation flux reflected by the surface of the body to the flux incident on its surface. For surfaces, scatter the incident solar radiation, this value is called the albedo.

Solar water heating. The conversion of solar energy into thermal energy is provided by the ability of the atoms of matter to absorb electromagnetic radiation. In this case, the energy of electromagnetic radiation is converted into the kinetic energy of atoms and molecules of matter, that is, into thermal energy. The result is an increase in body temperature.

For energy purposes, the most common use of solar radiation is for heating water in heating and hot water supply systems. The main element of the solar heating system is the receiver, in which the absorption of solar radiation and the transfer of energy of the liquid take place. The most common flat receivers, which allow you to collect both direct and scattered radiation and, considering this, are able to work also in cloudy weather. They are of low cost and are best when the liquids are heated to temperatures below 100°C.

The characteristics of some designs of the solar heating system are as follows:

– an open reservoir on the surface of the earth (e.g. a pool) is the most affordable water heater. The rise in water temperature is limited by the high coefficient of water surface reflection, heat transfer to the ground and air, the consumption of a part of the absorbed heat by the evaporation of water;

– an open tank (insulated from the ground). The rise of water temperature is limited by the high coefficient of water surface reflection, heat transfer to air, the consumption of part of the absorbed heat by the evaporation of water;

– a black tank (the liquid is in a container with a black matter surface), of course, is located on the roof of the house. Heat loss by evaporation is absent, the absorption coefficient of the black surface is close to unity. Heaters of this type are inexpensive, easy to manufacture, allow heating water to a temperature of about 45°C. It has significant spread in Japan and Israel;

– black tank (with a thermally insulated bottom). Allows you to reduce almost two to three times the heat loss that occurs in the previous design. To achieve this, only a few centimeters of the insulating layer is sufficient;

– closed black heaters (the capacity of the heater is placed in a container with a transparent cover for solar radiation, the best material for which is glass). Allow to exclude heat transfer from the receiver to the air, especially in windy weather;

– metal flow heaters (water flows through parallel tubes fixed on a darkened metal plate). Of course, the diameter of the tubes is about 2 cm, the distance between them is 20 cm, the thickness of the plate is 0.3 cm. The plate with windproof tubes is placed in a container with a glass lid.

The characteristics of the flow heater can be improved by reducing the convective transfer between the receiving plate and the glass cover and the radiation losses from the plate, and using vacuum collectors in which a black tube is filled with a liquid inside the outer glass tube and a vacuum is created in the space between them. The latter excludes convective heat transfer through the outer surface.

The liquid heated in the flow-through heater can be used immediately or left in reserve. The pumping of heated liquid can be carried out both by forced and natural circulation (convection). In the latter case, the heater should be located below the hot water storage tank. The pumping speed should be such that the water temperature rises by about 4°C every time the heater passes.

The advantage of the system with forced circulation is the possibility of using existing water heating systems by introducing a solar radiation receiver and a pump into their structure; It is not necessary to place the storage tank above the receiver. The disadvantage is the dependence on the electricity that the pump consumes.

Air heaters. Solar radiation can be used for heating air, drying grain, for heating houses. For the latter, more than a third of all primary energy resources are spent in the climate zone of Ukraine. Partial unloading of power, associated with the design or reconstruction of houses by using solar heat, can save a significant amount of energy carriers of heat supply systems.

The thermal conductivity of air is much lower than of water. Therefore, heaters of this type are made from roughened receiving surfaces that have a large heat exchange area, which makes it possible to significantly increase the heat transfer rate due to the flow turbulence.

Solar systems for generating electricity (solar power plants). The concentration of solar energy allows obtaining temperatures up to 700°C, which is sufficient for the operation of a conventional thermal engine with an acceptable efficiency. For example, a parabolic concentrator with a mirror diameter of 300 m allows us to concentrate the radiation power of about 700 kW, which allows us to obtain up to 200 kW of electric power. The collector transfers solar energy to the heat carrier (the latter in this case can be in the form of high temperature water vapor), which is sent to a steam turbine to generate electricity.

To create solar power plants of high power (about 10 MW), two options are possible: dispersed manifolds and systems with a central solar tower. A solar power plant with dispersed collectors consists of a number of small concentrating collectors, each of which independently monitors the Sun, transfers the energy of a liquid (coolant) that collects from all collectors in a central power station and enters the turbine of an electric generator.

A solar power plant with a central tower consists of flat mirrors located on a large area that follow the sun and reflect the sun's rays on a central receiver located on top of the tower.

Accumulators of thermal energy. The application of the standard heaters described above is too expensive to heat large volumes of liquid to temperatures of 100°C. In this case, the effective use of a "solar pond", which looks like an original heater, where the heat-protective surface is water.

Several layers of water of varying degrees of salinity are flooded in the "solar pond" (a fairly large pond dug right in the ground). The layer of the highest salinity of about 0.5 m thick is located on the bottom and is heated by solar radiation, which is absorbed by the bottom of the reservoir.

Thus, in a heterogeneous water body the bottom layer of water is saltier than the layer above it, and its density, although it decreases with heating, remains above the density of the higher layer. The absence of convection, which is observed in this case, contributes to the fact that the bottom layer heats up more and more. The use of solutions, the density of which increases when heated, allows you to have stable solar ponds in which temperatures of 90°C and above are reached. For example, solar bets in Ein Bokek (Israel) produce 150 kW of electricity from an area of 0.74 hectares at a cost of 0.1 US dollars per 1 kW.

Direct conversion of solar energy into electrical energy (photoelectric converters). The most optimal is the direct conversion of solar energy into electrical energy, which becomes possible when using the photoelectric effect.

The photoelectric effect is an electrical phenomenon that occurs when the substance is illuminated, namely: the output of electrons from metals (photoelectric emission or external photoeffect), the transfer of charges across the semiconductor interface with different types of conductivity. When illuminating the interface of semiconductors with different types of conductivity, a potential difference arises between them. This phenomenon is called a gate effect, based on the creation of photoelectric energy converters (solar cells and batteries).

The phenomenon of the photoelectric effect in semiconductors was discovered in 1876 in Selenium. For more than 100 years, it has been intensively researched and used in practice. However, practical application for the power of silicon so-lar batteries began only in 1958 after the launch of Earth satellites. Since then, solid-state solar panels are the main and almost the only sources of power sup-ply for spacecraft. More recently, it was believed that the photoelectric method of solar energy conversion is promising only for solving particular problems, in particular for autonomous power systems in hard-to-reach or remote areas.

Until recently, the most studied semiconductor material, which met the requirements for the creation of photocells based on it, was silicon, so photocells were made from it.

As it is known, the intensity of solar radiation varies significantly depending on the time of year and day. Therefore, the problem of using the energy of the sun encounters the need for its accumulation and storage for a certain time. Of all the ways of accumulating solar energy, its transformation into a chemical result of photochemical reactions is considered promising.

Solar cells are characterized by the coefficient of conversion of solar energy into electrical energy, which is the ratio of the radiation flux incident on the element to the maximum power of the electrical energy produced. Silicon solar cells have a conversion factor of 10-15%, that is, with an illumination of 1 kW/m^2 produce an electrical power of 1-1.5 W from each square decimeter.

The typical structure of a solar cell with a junction is shown in Fig. 7.6. It includes a layer of semiconductor 1 with a thickness of 0.2-1.0 microns in n-conductivity, a layer of semiconductor 2 with a thickness of 250-400 microns with p-conductivity, an additional potential barrier 3 with a thickness of 0.2 μm, a metal contact 4 on the rear side, the connecting conductor 5 with the face of the previous element, reflecting the covers 6, the facepiece 7, the connection conductor 8 to the contact of the next element.

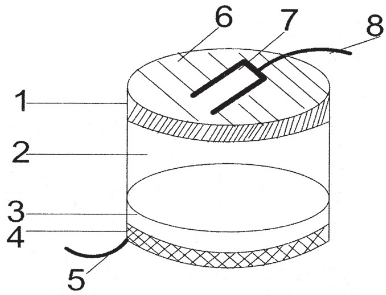


Figure 8.1. Solar Cell

Solar cells are connected in series to solar modules, which in turn are connected in parallel to solar batteries (Fig. 8.2).

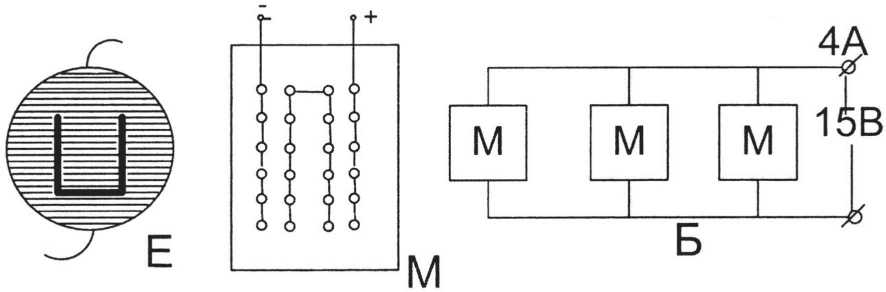


Figure 8.2. Schemes of The Working Element, Connections of Elements in the Module and Battery Modules: E – solar cell, M – solar module, B – solar battery

Solar receivers are used in power supply and cooling systems of rooms, in technological processes that occur at low, medium and high temperatures. They are used to produce hot water, desalination of sea or mineral water, for drying materials and agricultural products, and the like. Thanks to solar energy the process of photosynthesis and growth of plants is carried out, various photochemical processes take place.

There are passive and active solar thermal systems

Passive systems are, as a rule, fixed devices, solar collectors (SC), oriented at a certain angle to the horizon to the south. This can be the walls and roof of houses, where SC are located. In a certain way, painted, glazed, they make it possible to obtain at the expense of solar radiation low-temperature heat, used for heating, ventilation of premises, heating water and the like.

Active thermal solar systems have special devices, through which solar collectors "follow" the location of the Sun. In such systems, temperatures from 100 to several thousand degrees Celsius are achieved.

Passive solar systems are used for many years – greenhouses, terraces of houses, directed to the south. These systems are based on such an important direction in energy and construction as "solar architecture". Its role has increased especially in recent years, the fuel quantity and operation of conventional heating systems have increased many times and when we have learned to estimate the environmental losses through contamination. Experience shows that passive solar systems can provide from C up to 60% of the heat required for heating and hot water supply of premises.

Solar collectors are the main elements of thermal solar systems, both passive and active. Basically, they are flat and contain tubular or flat heat exchangers, in which heat carriers are heated due to the absorption of solar radiation. There are collectors with a natural and forced (with the help of pumps) circulation of the coolant. Collectors with forced circulation of coolant area of 1.5 m^2 can heat for 5-6 hours on average 100 liters of water to 70-80°C, that is, one collector is able to provide a small family with hot water for one day.

Flat collectors are used mainly in hot water supply systems; for heating and air conditioning systems, like water and air heaters, to produce low pressure steam. They are installed directly as an integral element of the wall or roof of the house with the optimal orientation depending on the time of the year. Focusing collectors use optical systems – mirrors or lenses – to increase the density of solar radiation on a surface that absorbs energy (this allows to reduce its area, and consequently, to reduce heat losses).

Now, in the world, there are solar power stations that use different principles of energy conversion, as well as high-temperature solar furnaces designed for obtaining pure materials, testing SES nodes and other purposes. Solar installations are used in power supply and cooling systems of rooms, in technological processes that occur at low, medium and high temperatures.

Advantages and disadvantages of solar energy

The main advantages of solar energy are accessibility and inexhaustibility; Noiseless production of solar energy and complete safety for the environment (however, currently the production of photocells and in them themselves use harmful substances).

The drawbacks of solar energy include the need to attract large areas of land for power plants; unevenness of the flow of solar energy; dependence on time of day and weather conditions; high price of solar photocells; low efficiency of solar panels; the complexity of technical support and maintenance.

The issue of absolute safety of solar energy technologies for the environment is controversial. Today, in the manufacture of solar cells, harmful substances are used, such as lead, cadmium, gallium, arsenic. The service life of solar batteries is 30-50 years, so there is a problem of further processing of modules, and the solution of the issue of their utilization has not been found yet. However, this type of energy is becoming more common every year, new developments and technologies are emerging, therefore, all listed shortcomings are only temporary.

8.3. State and Prospects of Solar Energy Development in Ukraine

The average annual potential of solar energy in Ukraine is 1235 kWh/m and much higher than, for example, in Germany – 1000 kWh/m or even in Poland – 1080 kWh/h. So, Ukraine has significant opportunities for effective use of heat and power equipment.

On the use of solar radiation for energy production, the technically permissible potential of solar energy from the roofs of the housing stock of Ukraine today is 26-37 TWh/year. The main engineering element of the solar system are solar collectors that convert the energy of the sun's rays into thermal or electrical energy. The power of such solar batteries is 70-100 W for 1 m^2 of the collector surface. The electric power received in this way is still quite expensive, but the use of photoelectric collectors allows to autonomize the energy supply of the building.

Implemented in recent years, experimental projects have shown that the annual production of thermal energy in Ukraine is 500-600 kWh/m^2. Taking into account the common potential in the West for using solar collectors for developed countries equal to 1 m^2 per person, as well as the efficiency of solar installations for the conditions of Ukraine, the annual resources of solar hot water supply and heating can be 28 kWh/m^2 of thermal energy. The implementation of this potential would save 3.4 mln tons of fuel equivalent per year.

At the beginning of 2013, Ukraine had 372 MW of installed capacity of solar energy, 182 MW (95.8%) more than the previous year. On solar energy accounted for 6% of the power of all renewable sources and 0.7% of the entire generation. According to the forecast for 2017, the installed capacity of solar energy will reach 3087 MW.

Ukraine has enough favorable climatic conditions and industrial infrastructure that meet the needs of intensive development of solar energy. Considering the world experience, the following are the priority directions of development of solar energy in Ukraine:

- mastering the technologies of passive solar heating of buildings;
- introduction of hot water and heating systems using solar collectors;
- creation of highly efficient equipment for photovoltaic power engineering;
- use of combined solar-fuel power plants and boiler houses.

The main objectives of the development of solar energy in Ukraine should include:

1. Development of typical architectural and technical solutions for the construction and modernization of residential, administrative and industrial premises for the purpose of introducing energy-saving solar heating technology – "Sunny House";

2. Development of design and technology and the establishment of a series production of high-efficiency solar collectors for the needs of the population and industry enterprises;

3. Perform R & D (research and development work) to create high-efficiency photovoltaic modules based on helium arsenide and with solar concentrators; Development of technological schemes, projects and construction of experimental photovoltaic stations and combined solar-fuel power stations;

4. Creation of a network of service enterprises for the construction and service of solar energy facilities.

Thus, today in Ukraine the most promising are such areas of solar energy use as:

– direct conversion of it into low-potential thermal energy without a preliminary concentration of the solar radiation flux (for hot water supply of facilities, municipal and technological heat supply, agricultural needs) with an efficiency factor of 45-60%, and in the case of concentrators – 80-85%;

– direct conversion of it into direct current electric power by means of photoconverters (photomodules) with an average efficiency of 10-15%, although there are promising developments with an efficiency of about 30%.

The optimally selected equipment reduces the annual energy use for water heating by 50-60% and energy from the network by 50-70%. Between April and September, the correctly installed system covers 95% of the heat and energy costs. In Ukraine, the technical potential of solar radiation, suitable for the production of electricity, is estimated at 16 TWh per year, which is about 3.3 m^2 of photovoltaic cells per capita with a production of 100 kWh in them per year. Even if residential buildings are equipped with modern energy-saving household appliances, this amount of energy can provide vital household needs. It is forecasted that in 2030 in Ukraine the production of electricity by solar photovoltaic installations will be 2 TWh per year, and in 2050 it will reach 9 TWh per year.

Basic definitions and concepts. *Solar energy. Hydrogen. Helium. Solar radiation. Organic fuel. Glucose. Solar radiation. Convection. Photons. Solar collectors. Passive systems. Active systems. Flat collectors. Focusing collectors. Photoelectric effect. Solar panels. Kilowatt. Photochemical reactions.*

Test questions and tasks

1. What is solar energy?
2. What is the potential application of solar energy in the world?
3. Describe the physical basis for the use of solar energy.
4. What are the types of solar collectors?
5. What are passive solar cells and where are they used?
6. Describe the main points of solar energy conversion in natural photosynthesis.
7. Bring the technical and economic aspects of solar energy.
8. How does the photoelectric conversion of solar energy occur?
9. What are the main advantages and disadvantages of solar energy?
10. Describe the main objectives of solar energy development in Ukraine.

CHAPTER 9
WIND ENERGY

Key issues

9.1. History of Development and State of Wind Power in the World

The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses, schools, and the like.

The source for the formation of wind energy is the Sun, as its activity causes the formation of wind. The Earth's atmosphere absorbs solar radiation unevenly due to heterogeneity and surface and a different angle of incidence of light in different latitudes at different times of the year. The air expands and rises, forming streams. Where air is heated more, these flows rise higher and focus in low pressure areas, and cold air remains lower, creating high pressure zones. The difference in atmospheric pressure causes the air to move from the high pressure zone to the low pressure zone at a proportional speed. This movement of air is called wind.

The use of wind energy is one of the oldest known ways of using energy from the environment. Mankind has been using wind energy for more than

5000 years. One of the first inventions that used wind power was the sail. About 3500 BC, seafarers used the power of the wind to go under sail. Sailboats sailed around the Nile in Ancient Egypt. Conventional windmills worked in China 2200 years ago. In the Middle East, in Persia, about 200 BC it has begun to use windmills with a vertical axis for grinding grain, they were made of reed knots attached to a wooden frame, rotating when the wind blew.

The first windmill manufactured in the United States was designed by Daniel Halladay, who began inventing windmills in 1854 in his Connecticut machine shop. The windmill was hugely successful as a means of pumping water on farms and ranches in the expanding western frontier, so much that Halladay moved his operation to Illinois. Additionally, the windmill played a key role in the expansion of the railroads because water was required for the operation of the early steam-driven engines. Eventually, more than 1,000 small and large factories began operations to produce water-pumping windmills, with one company selling nearly 100,000 in one year at the peak of the market. Between 1850 and 1970, more than six million mechanical windmills were installed in the United States.

The first electricity-generating wind turbine was invented in 1888 in Cleveland, Ohio by Charles F. Brush. The turbine's diameter was 17 meters (50 feet), it had 144 rotor blades made of cedar wood, and it generated about 12 kilowatts (kW) of power.

The incorporation of small, wind-powered electric generators by farmers and ranchers was not a difficult transition, given the longtime success of mechanical water-pumping windmills. During the early 1900's, small wind turbines produced 5 kW to 25 kW of power. They were used throughout rural areas in the United States to provide electricity to remote locations.

On May 11, 1935, the United Stated Federal Rural Electrification Administration (REA) was created to promote the expansion of electrical service to rural areas where existing private electric companies would not expand, namely due to the high costs involved in stringing electric lines to remote farmsteads. With the expansion of these power lines, farms received a more dependable, usable energy for a given amount of capital investment, and the electric wind turbine industry no longer was the first choice in rural electric power.

In the Soviet Union, the first wind power station with an output of 8 kW was built near Kursk in 1929-1930. A year later, in the Crimea, a large wind farm with a capacity of 100 kW was built, at that time it was the largest in the world.

In recent years, the wind is increasingly used to generate electricity. High-capacity wind turbines are being built and are installed on the terrain with frequent and strong winds. The number and quality of such engines is growing every year, serial production is established. The average annual increase in world wind energy averages 26-27% and is the highest in comparison with other sources of energy.

The wind energy sector currently employs more than 70 countries. Recently, the World Council on Wind Energy published a report identifying the leading countries in the field of wind power. The countries with the largest consumption of wind energy per population were Denmark, Spain, Portugal, Sweden, Germany, Portugal, the USA, Canada.

Although Denmark has a relatively small wind speed in the range 4.9-5.6 m/s at a height of 10 m, it generated enough wind energy to power the entire country's electricity needs. According to WindEurope, Denmark generated a total of 70 gigawatt-hours (GWh) from onshore wind and another 27 GWh from offshore wind – enough to power the equivalent of 10 million average EU households. This is not the first time wind power has dominated generation statistics in Denmark, with several big wind energy days back throughout 2015. By the end of 2015, the country had a total of just over 5 gigawatts (GW) worth of wind energy installed – made up of 3799 megawatts (MW) of onshore wind and 1271 MW of offshore wind – a number which likely would have increased during 2016. Besides, 18.8 percent of European electricity demand was met by wind power and 52 percent of it in Germany.

1-2% of sun energy total amount turns into wind energy. This amount is five times higher than the annual global energy demand. Of course, the possibilities of using wind power in different regions of the Earth are not the same. For normal operation of wind turbines, the wind speed should not drop on average for the year below 4-5 m/s, but better, when it is 6-8 m/s. However, for wind turbines too high wind speeds (hurricanes) are harmful, which can destroy them. The most favorable regions for the use of wind energy is the coast of the seas and oceans, steppes, tundra, mountainous areas.

With almost 300 TWh generated in 2016, wind power covered 10.4 % of the EU's electricity demand. Five EU Member States had a record year in new wind energy installations in 2016: France (1.6 GW), the Netherlands (887 MW), Finland (570 MW), Ireland (384 MW) and Lithuania (178 MW). Turkey (1.4 GW) also broke its record for annual new installations.

Wind energy today has ceased to be fiction and is growing at the fastest pace among all alternative energy sources. The wind is an unusual energy carrier, inexhaustible, but it has a lot of complex and slightly overdubbed physical parameters for every single geographic region.

9.2. Technical and Economic Features of Wind Turbines

The principle of operation of all varieties of wind aggregates is the same. The wind rotates the wind wheel with blades and transmits the torque to the shaft of the generator that generates electricity. All existing types of wind aggregates can be classified as follows:

1. By appointment: for the production of electricity; to raise water; to produce heat.
2. Power: low power (up to 100 kW), average power (100 to 500 kW), megawatt class (0.5-4 MW and higher).
3. The direction of the axis of the wind receiving equipment (former Contribution 10):
   A) with a horizontal axis of rotation: a parallel direction of the wind flow;
   B) with a vertical axis of rotation perpendicular to the direction of the wind flow: with two-tier vertical blades on the common shaft; with two blades in the vertical plane, located on wheelchairs and inclined to the outer side of the axis, and also joined by a horizontal wing into a single structure with a central support; with many blades located on wheelchairs, interconnected, which move in a circle with a diameter much greater than the height of the blades.
4. By the number of blades of the wind wheel: 2 blades, 3 blades or more.
5. According to the type of the wind wheel: winged, rotary.
6. On working conditions: isolated, in the energy complex for emergency situations, hydroelectric power stations, hydroelectric power stations, SES and diesel plants.
7. When working in the power system: connected to the power system, connected autonomously to the consumer.

Of all the devices that convert wind energy into mechanical work, the vast majority use bladed machines with a horizontal shaft installed in the direction of the wind, much less often – devices with a vertical shaft. Turbines with a horizontal axis and a high speed factor have the highest value of the wind energy use factor (0.46-0.48). Wind turbines with a vertical axis arrangement are less efficient (0.45), but do not require tuning for wind direction.

Advantages and disadvantages of wind energy. There are many advantages of wind energy, including energy, environmental, economic. The total kinetic energy of the wind in the world is 80 times higher than the total energy consumption. And although only a certain proportion of this total indicator can be used for energy needs, the future development of the technology itself has enormous potential.

The main advantages of wind power are as follows:

1. A renewable energy source, reduces dependence on fossil fuels, reduces emissions of greenhouse gases and other harmful gases and contributes to combating climate change.

2. Wind energy is available in virtually any country and does not depend on fluctuations in the prices of fossil fuels, the reserves of which are steadily declining. Over the past decades, the cost of wind-driven electrical installations, the costs of installing and servicing them has dropped significantly. In the future, these costs will continue to decrease. Even small consumers can afford to install a small windmill, especially in countries where grants and incentives exist for the development of wind power.

3. Rapid development of the global wind energy market, which leads to a significant drop in prices for energy received by wind. Modern wind farms annually produce 180 times more electricity than 20 years ago. At the same time, the kilowatt of energy produced fell by half at least. With a successful location, wind power stations can compete economically with nuclear and thermal power plants.

4. Modern wind energy is one of the most developed and promising branches of renewable energy. The United Nations Program on the Development of World Energy, in particular, emphasized that in the 21st century the developed countries will be those, where wind energy is developing intensively. According to the World Energy Council's estimates on «minimum» and «maximum» options for the development of renewable energy, the contribution of wind energy to global energy production in the world in 2020 will be 122 and 307 million tons of equivalent fuel, respectively.

Main disadvantages and limitations:

1. One of the main limitations of wind power development is the need to locate installations in certain areas with high wind intensity. Another limitation is the need to decommission land that could be used by other types of economic and environmental activities. But the cost of land for wind farms is much less than for traditional power plants.

2. Relatively high investments in wind energy projects in comparison with traditional fossil fuel energy industries.

3. Environmental imperfections: noise effects; possible harm to birds, bats, other animal species; stroboscopic effect in the northern regions. The main potentially harmful impacts of wind turbines on birds are collisions with moving blades of wind turbines, with parts of adjacent structures, in particular power

lines, or with airflow with a turbine, which can lead to injury, increased mortality; forced movement of birds from the area around the windmill or the whole area around the wind farm.

Many of the described problems can be solved in the process of technology development, but the issue of the negative influence of the bird population requires further study and consideration when planning the wind energy project. However, modern megawatt-type windmills do not destroy birds, as any bird can see well a wind wheel that rotates at a speed of 20-30 turn/min. Since 1993 even the Ukrainian statistics has not recorded cases of destruction of birds on the operation of about 700 wind power plants with a capacity of 107.5 kW, the wind wheels of which rotate at a speed of 72 turn/min.

9.3. Status and Prospects of Wind Energy Development in Ukraine

In Ukraine, in 1917, there were 20-30 thousand wind turbines, which produced 120-200 thousand kWh of energy. But gradually, until 1955, their number decreased to 8500. In the mid-1960s, only a few hundred wind turbines with an installed average capacity of about 4 kW were operated in agriculture, mainly for water supply, the production of direct current, the grinding of grain. By 1982 their number decreased to 15 with the generation of electricity about 10 thousand kWh. In another words, wind power was almost not used in these years.

According to the scientists of the Institute of Electrodynamics and the Institute of Renewable Energy of the National Academy of Sciences of Ukraine, our country has significant potential in the field of renewable energy sources.

Since 1997, when the Integrated Program for the Construction of the Wind Power Station was adopted, wind power in Ukraine received state support in the form of a surcharge to the tariff for electricity and direct financing. In 2008, The Verkhovna Rada adopted a number of decisions to support the production of alternative energy sources, in particular, the "green tariff" for electricity received from alternative sources was approved.

According to the Interindustry Scientific and Technical Center for Wind Power Engineering of the National Academy of Sciences of Ukraine, the territory of our country has significant wind energy resources estimated at 30 TWh/year.

As a result of the processing of statistical meteorological data on the speed and frequency of wind speed, zoning of the territory of Ukraine was carried out and the specific energy potential of the wind at different altitudes was determined, respectively, to zonation zones.

The data given are basic for the introduction of wind power equipment and intended for use by designers of objects of wind energy for establishing the optimal power of wind generators and the type of energy (electric or mechanical) for efficient production in a particular area.

In Ukraine, using wind turbines it is possible to use 15-19% of the annual volume of wind energy passing through the section of the surface of the wind wheel. The expected volume of electricity production from 1 m^2 of cross-section of the area of the wind wheel in the prospective regions is 800-1000 kWh/m^2 per year.

The use of wind turbines for the production of electricity on an industrial scale is most effective in the regions of Ukraine, where the average annual wind speed is more than 5 m/s: on the Azov-Black Sea coast, in Odessa, Kherson, Zaporizhia, Donetsk, Lugansk, Mykolaiv regions, Crimea and in the Carpathians.

Operation of low-speed multi-blade wind turbines with increased torque for performing mechanical work (grinding grain, raising and pumping water, etc.) is effective practically throughout the territory of Ukraine. Significant growth in the construction of wind farms is observed after the introduction of the "green tariff" by the government of Ukraine.

Thus, on December 31, 2016, the total installed capacity of the wind power industry in the mainland of Ukraine is 437.8 MW. All wind farms are connected to the grid and supply electricity to the United Energy System of Ukraine.

In 2016, from the wind farm of the mainland of Ukraine, 924483000 kWh of electricity were sold at a "green" tariff in the UES of Ukraine. The supply of electric power by wind farms that are located on the territory of the Crimea (88 MW) has been suspended in the IPS of Ukraine since April 2014.

On 13 April 2017 the Ukrainian parliament adopted a bill No. 4493 On Electricity Market of Ukraine. The bill paves the way for the full implementation of the third EU energy package requirements in the national electricity sector. It also provides for two years' transition period for implementing completely new for Ukraine market segments – day-ahead market (indicative market prices), intraday market, bilateral contracts market, balancing and ancillary services markets.

With respect to renewables, the Electricity Market Draft Law introduces responsibility of the respective producers for the hourly imbalances at the day ahead market where they will sell electricity at "green" tariff. It is planned that the responsibility for solar and wind will be introduced gradually with increase by 10% annually starting with 2021 until 2030 with 20% tolerance for wind, 5% tolerance for small hydro as well as 10% tolerance for solar. It also envisages the possibility of signing preliminary PPA before construction when a producer of electricity from renewables has executed title documents in respective lands, obtained a construction permit and signed a grid connection agreement. The producers of electricity from renewables, which have commissioned their power plants before the bill entry into force, are exempt from liability for imbalances until 2030.

The payback period of a wind power plant, depending on the terrain, provision of communications, capacity of the installation, etc., is from 3 to 8 years. Specific capital costs for low-power stations fluctuate within $ 800-1000 per 1 kW of installed capacity and decrease with increasing plant capacity. Therefore, the capital costs for a wind power plant with a capacity of 250 kW (Denmark) reach $ 40,000 with a payback period of 6.7 years.

Wind energy of Ukraine has acquired sufficient experience in the production, design, construction, operation and maintenance of both wind power plants and wind power stations; the country has a sufficiently high scientific and technical potential and a well-developed production base. Recently, the development of wind energy sectors is affected by state support, provides for the implementation of initiatives to improve legislation, governance structure, creating favorable conditions for domestic and foreign investors.

Basic definitions and concepts. *Wind power. Wind power station. Windmill. Blade. Generator. Meteorological data. Wind turbines. Wind-wheel. Axis of rotation. Torque. Mechanical work. Wind turbine. Vane and rotor wind wheels.*

Test questions and tasks

1. Give a definition of wind energy, describe its structure.
2. Analyze the history of wind energy development.
3. Describe the current state and prospects of wind energy development in Ukraine.
4. How are wind power plants classified?
5. Describe the advantages and disadvantages of wind power.
6. Which countries are the leaders in the field of wind energy?
7. What is the reason for the development of wind power in Ukraine?
8. What is the share of output of wind farms in total electricity production in Ukraine?
9. Analyze the reasons for the unsatisfactory state of Ukrainian wind energy.
10. What are the main directions of wind energy development in Ukraine?

CHAPTER 10
SMALL HYDROPOWER

Key issues

10.1. Technical, Economic and Environmental Aspects
of The Development of Small Hydropower
10.2. World Experience of Small Hydropower Development
10.3. State and Prospects of Small Hydropower in Ukraine

10.1. Technical, Economic and Environmental Aspects of The Development of Small Hydropower

Hydropower, as the largest clean and renewable energy source, has played an essential role in the global energy mix. Against the backdrop of rapid social-economic development and global warming, the development of renewable energy has gained increased attention among the global community. The manifold benefits of small hydropower – the relatively low investment capital, small engineering work, simplistic maintenance and operation, minimal environmental impacts, suitability for scattered development in rural and remote areas – have attracted special attention from the global community. Small hydropower has seen rapid development in many countries, making important contribution to meeting daily electricity demand, reducing poverty and advancing socio-economic improvement.

Small hydropower has greatly contributed to solving the problem of rural electrification, improving living standards and production conditions, promoting rural economic development, alleviating poverty as well as reducing emissions. Moreover, small hydropower is an economically efficient technology, and as such, has been highly favoured by the international community, especially by developing countries.

Due to the lack of a fuel component of the cost of energy generated at HES and low operating costs, it is the cheapest of all traditional energy sources. But the construction of powerful hydroelectric power plants leads to significant economic losses due to the removal of large areas of the most lands, adversely affects the biosphere, changing the habitual balance of natural ecosystems, causes social tension as a result of resettlement of people in new, often worse terrain.

Turbines of small HES can be used as energy dampers at elevations of pipelines, designed for pumping various types of liquid products. In addition, in order to partially compensate for electricity, the installation of small power units is possible on technological waterways, industrial and sewage discharges, etc. Small hydropower should first of all be used in such remote and inaccessible areas where there are no power lines nearby, as building such lines most often more expensive than installing a small HES.

One of the most urgent tasks is the creation of efficient, reliable and inexpensive equipment for micro and small hydro power plants. As an engineering basis for the production of such equipment, almost all types of classical hydroturbines can be used, but an analysis of their capabilities in terms of used heads, dimensions of hydraulic units, cost of manufacturing equipment and construction has shown that the use of classical hydraulic turbines for this purpose is not always rational. Hydraulic aggregates with a classical type of turbines, especially for low heads (2-15 m), complex in construction, more expensive to manufacture and require significant costs for the construction of hydraulic structures. The construction of dams on such watercourses to increase the pressure and use of other types of classical turbines leads to flooding of significant areas, it is inexpedient from an economic and ecological point of view. Experience shows that the automatic transfer of the principles of creating equipment and technical solutions from large hydropower to small in the root is incorrect. The creation of equipment for micro and small hydro power plants requires completely different approaches. The optimal way to solve this problem is to create high-efficiency flow parts of cross-jet or double turbines, as well as their perfect designs based on turbines of the "jar" type. The flow part and the designs of cross-flow jet turbines were constantly improved in terms of improving their energy and performance characteristics. The maximum efficiency of such turbines, achieved in the world, is about 90%. The simplicity of design, low cost, reliability of operation with sufficiently high energy efficiency makes it possible to consider cross-jet turbines as a priority type of turbines for equipping them with units of micro and small hydropower.

Under the same conditions, the cross-jet turbines are smaller in size, and also need significantly less costs for the construction of hydraulic structures in comparison with classical turbines.

Such turbines can be operated at pressures from 1 m and obtain considerable power in the presence of sufficient water flow, because the costs and power at the same pressure of water can vary, unlike classical turbines, not only in the diameter of the impeller, but also its length. It should be noted that the range of use of cross-jet turbines is unusually wide. This type of turbines for units of micro and small HES can be used for pressures from 1.5 to 180 m. There is a real possibility of creating on the basis of cross-jet turbines of the same type of equipment for micro- and small HES in a wide range of pressures and capacities instead of different types of classical turbines.

10.2. World Experience of Small Hydropower Development

Humans have been harnessing water to perform work for thousands of years. The Greeks used water wheels for grinding wheat into flour more than 2,000 years ago. The evolution of the modern hydropower turbine began in the mid-1700s. In 1880, a dynamo driven by a water turbine was used to provide arc lighting– a technique where an electric spark in the air between two conductors produces a light – to a theatre and storefront in Grand Rapids, Michigan, and in 1881, a dynamo connected to a turbine in a flour mill provided street lighting at Niagara Falls, New York; both of which used direct current technology.

The past century of hydropower has seen a number of hydroelectric advancements that have helped it become an integral part of the renewable energy mix. Into the 21st century, hydropower continues to catalyse growth around the world.

The globally installed SHP capacity is estimated at 78 GW in 2016, an increase of approximately 4 percent compared to data from WSHPDR 2013. The total estimated SHP potential has also increased since publishing WSHPDR 2013 to 217 GW, an increase of over 24 percent. Overall, approximately 36 percent of the total global SHP potential has been developed as of 2016.

SHP represents approximately 1.9 percent of the world's total power capacity, 7 percent of the total renewable energy capacity and 6.5 percent (< 10 MW) of the total hydropower capacity (including pumped storage). As one of the world's most important renewable energy sources, SHP is fifth in development, with large hydropower having the highest installed capacity to date, followed by wind and solar power.

While the USA has developed a majority of its potential, reaching 57 percent of its developed potential in 2016, Brazil has much of its SHP potential undeveloped, reaching only 30 percent in 2016. Nevertheless, since the publishing of WSHPDR 2013, Brazil has increased its installed capacity by 34 percent (up to 30 MW). The US, however, had decreased 46 percent in installed capacity based on more accurate data in 2015. Europe has the highest SHP development rate, with nearly 48 percent of the overall potential already installed (Figure 10.1).

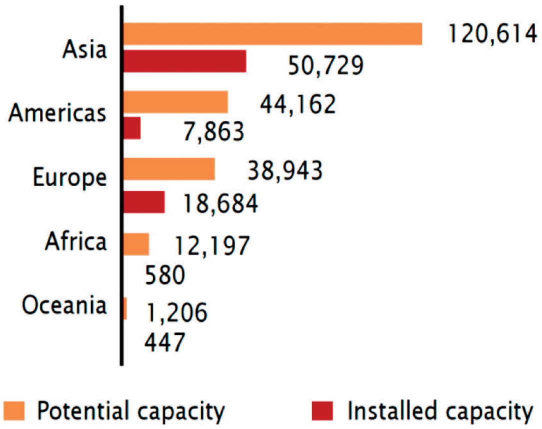


Figure 10.1 Small Hydropower by Region (< 10 MW)

Japan and India also have a less developed SHP sector, reaching only 35 and 18 percent of developed potential in 2016 respectively. Compared to data of 2013, India's total installed capacity has increased by 18.6 percent (up to 25 MW). Japan, however, has increased 0.8 percent.

10.3 State and Prospects of Small Hydropower in Ukraine

In Ukraine, according to the Law of Ukraine "On Electric Power Industry", hydropower plants, whose capacity does not exceed 10 MW, belong to the SHP.

SPP with capacity up to 1 MW are conditionally classified into micro-HPPs (from 0.1 to 100 kW) and mini-HPPs (up to 1000 kW).

Small hydropower in comparison with other non-traditional sources of energy is a priority source. First of all, this is determined by the fact that:

– the generated electricity at SHP can be used to cover the peak power deficit in the power system;

– frequency regulation, voltage and power redundancy through the development of generation at SHP provides improved quality and reliability of power supply (in contrast to wind farms and solar power plants whose operation is completely dependent on meteorological conditions);

– the construction of SHP is of great infrastructural importance, since it makes it possible to provide water storage for needs of the national economy and the protection of adjacent territories and settlements from floods, creates conditions for the regulation of watercourses and promotes the development of local fisheries.

The list of potential sources of electric power for small-scale power engineering is unusually wide. These are rivers, streams, natural differences in altitude on lake spillways and on irrigation canals of irrigation systems. Hydropotential of small rivers of Ukraine exceeds the potential of large rivers fourfold. In Ukraine, there are more than 63 thousand small rivers and watercourses with a total length of 135.8 thousand km. Most small rivers with a length of less than 10 km have a catchment area of 20 to 500 km^2 (87% of the total and 72% of the total length of the country's small rivers). Small rivers with a catchment area from 50 to 100 km2 have 890 (28% of the total), and with a catchment area of 20 to 50 km^2 – 797 (25% of the total).

The Carpathian rivers are characterized by the greatest water content, the drainage of which largely depends on the height of the basin. When using the energy resources of small rivers, the state of freezing on the rivers in winter is of particular importance, which is important for micro-HP using the kinetic energy of the stream.

In Ukraine, there are 260 reservoirs with a capacity of 10-100 million m^3, suitable for constructing micro hydropower plants and mini-HPPs with a power from 500 to 2000 kW each with a head of 5-10 m. Such hydroelectric power plants do not break the chain of biological and hydrochemical processes, in fact do not affect the natural regime of the watercourse, the river bed and the state of the shores. They help to regulate the level of groundwater, reduce soil erosion. As the power facilities of the SHP are constant (as a source of stabilization of the energy system in the event of a violation of its survivability), as well as increased competitiveness in the event of rising prices for organic fuels.

Relatively high specific investment remains the constraining factor, in particular for the construction of the dam. In the case of a comprehensive solution of energy, water and social problems, the "energy" share of capital investments is significantly reduced.

The decisive incentive for the restoration of abandoned and construction of new hydropower plants is the possibility to privatize of water management facilities together with the land plot.

The replacement of diesel and gasoline electrical installations at micro hydro power stations is generally beneficial, not to mention positive biological effects. Small reservoirs play the role of a biological treatment plant and contribute to an increase in oxygen in the water of the lower tail after passing it through the hydroturbines, which has a positive ecological effect.

Basic definitions and concepts. *Power-to-weight ratio. Small hydropower. Operating costs. Irrigation canals. Irrigation systems. Power unit. Workingwheel. Cross-flow jet turbines.*

Test questions and tasks

1. What makes small hydropower plants the cheapest of all non-traditional energy sources?
2. What are the potential sources of electricity for small hydropower?
3. How can we use small hydroelectric turbines?
4. Analyze the actual problems of the development of small hydropower.
5. What are the advantages of hydraulic units with a classical type of turbines?
6. What is the essence of the world experience of small hydropower development?
7. Describe the state of small hydropower in Ukraine.
8. What factors hamper the effective development of small hydropower in Ukraine?
9. What is the decisive incentive for the restoration of abandoned and construction of new SHPs?
10. What is the upper limit of the power of small hydropower equipment?

CHAPTER 11
GEOTHERMAL ENERGY

Key issues

11.1. The Essence and Significance of Geothermal Energy
11.2. Geothermal Power Plants and Heat Pumps
11.3. Potential of Geothermal Energy of Ukraine

11.1. The Essence and Significance of Geothermal Energy

Geothermal energy is the heat from the Earth. It is clean and sustainable. Resources of geothermal energy range from the shallow ground to hot water and hot rock found a few miles beneath the Earth's surface, and down even deeper to the extremely high temperatures of molten rock called magma. The temperature of the earth's deep crust (also called as geothermal gradient) has increased by 2.5-3°C every 100 m, so at a depth of 20 km, it is about 500°C, at a depth of 50 km – about 700 – 800°C. In some places, especially along the edges of tectonic plates of the continents and in the so-called "hot spots", the gradi-ent's temperature is almost 10 times higher, and then at a depth of 500-1000 meters, breeds temperature reaches 3000. However, where the temperature of terrestrial species is not as high, geothermal energy is enough.

For the first time, a centralized heat supply system using geothermal energy started in the 14th century in France. Industrial use of geothermal sources began in 1827 in Italy, when using a pair extracted boric acid from the contents of mud volcanoes.

In the US, the heating system, which operated exclusively on geothermal energy, appeared in 1892. Later in 1926, people began to use geysers for heating greenhouses in Iceland, and later – for heating houses.

In 1852 using another heat pump invented by William Thomson, Mexican-Swiss engineer Heinrich Zoelli in 1912 patented the idea of using this pump to get steam from under the earth. However, in the opinion it was possible to realize only in the late 1940s. In 1946, J. Donald Crocker designed and demonstrated the first commercial version of a heat pump. And in 1948, Professor of Ohio State University Carl Nielsen built a similar installation near his home.

In 1960, the first geothermal power plant with the capacity of 11 MW started operating successfully in the USA in the state of California. This technology has become quite popular in Sweden after the oil crisis of 1973, but it was still perceived rather reserved around the world. However, after the invention of the 1979 polybutylene pipes, the efficiency of using geothermal energy has increased significantly.

In 1967, in the USSR, it was presented to the first power plant, working on the double cycle method. The new technology made it possible to generate electricity using much lower temperatures. In 2006, a similar power plant was built in Alaska, which could produce energy from water at a temperature of 57°C.

All the natural heat contained in the earth's crust can be considered as geothermal resources of two types:

- steam, water, gas;
- heated rocks.

Hydrothermal energy sources are divided into thermal waters, steam-water mixtures and natural steam.

To obtain heat accumulated in the bowels of the earth, first it must be raised to the surface. For this, wells are drilled, and if the water is hot enough, it rises to the surface in a natural way, at a lower temperature a pump may be needed. Geothermal water is an environmentally friendly source of energy, constantly being restored. It differs significantly from the other alternative sources of energy in that it can be used regardless of climatic conditions and time of year.

Geothermal energy is an almost inexhaustible source of energy for humans. The source of geothermal energy is heated water (steam) from the depths of the earth's crust. Now thermal waters are widely used for heating and hot water supply in Iceland, Australia, New Zealand, Italy and other countries.

The extraction of energy is carried out by systems that raise the coolant to the surface of the earth. In countries that do not have their own energy reserves, the interest in geothermal heat supply is particularly high. These are countries such as Iceland, New Zealand, Japan, Mexico.

Agricultural facilities that create, as a rule, a small thermal load (up to 5 MW), best correspond to the heat engineering characteristics of geothermal energy with a depth of wells of 1000-3000 m. One of such objects is the greenhouse. In many areas there are geothermal waters with temperatures of 140-180°C at depths 4-5 thousand meters. Such sources should be used for centralized heat supply of cities and industrial facilities.

The possibility of simultaneous use of low-yield oil wells for oil production and geothermal heat will give new life to closed or uneconomical industries.

11.2 Geothermal Power Plants and Heat Pumps

There are two types of geothermal stations: the first for the generation of current use steam, others – superheated geothermal water. The first has dry hot steam from the well enters a turbine or generator to generate electricity. At the stations of a different type, geothermal waters with a temperature of more than 190°C are used. The water naturally rises up the well, is fed to a separator where, due to the decrease in pressure, part of it boils and turns into steam. The steam is sent to a generator or turbine and generates electricity. This is the most common type of geothermal power plant.

Significant scales of development of geothermal energy in the future are possible only in the case of obtaining thermal energy directly from rocks. In this case, in places where dry hot rock is found, parallel holes are drilled, between which a system of cracks forms. That is, an artificial geothermal reservoir is actually formed, into which cold water is supplied, followed by steam or steam-water mixture.

The average temperature of the Earth at a depth of 3-5 m during the year is 10-13°C and above. This can be used for heating and cooling houses, industrial premises, livestock farms with heat exchangers and heat pump systems, which saves up to 50-70% of the heat used to create an optimal temperature regime in the premises. To do this, in the earth, according to a certain scheme, channels are laid for the movement of air, or pipes buried in which water (or another coolant) is supplied. Regardless of the circulating in such a system, due to heat exchange with the ground, such a heat pump can absorb the heat of the earth and transfer it to the house during the cold season or to transfer heat from home to the land in hot weather.

In some cases, the use of thermal geothermal pumps can save up to 2/3 of the energy used for heating.

Pumping heat from the soil can be done with a heat pump.

Even in the century before the British physicist William Thompson invented a device that he called a "heat multiplier", which laid the foundation for the development of this technology.

The heat pump is a multifunctional device that combines the functions of a heating boiler, hot water sources and air conditioning. The main difference from all other heat sources lies in the exceptional opportunity to use renewable low-temperature energy of the environment for heating and water heating purposes. These devices are sometimes called "heat pumps", thanks to their ability, so to speak, to "pump" heat from a low-temperature source to a high-temperature one. Such systems operate without fuel and practically do not pollute the atmosphere with harmful emissions. In addition, they save up to 80% of the energy used for heating. This device receives this energy.

From the environment, you only need to pay for those 20% of the en-ergy expended for the operation of the circulation pumps and the compressor.

Fig. 11.1 shows the operating principle of the heat pump.

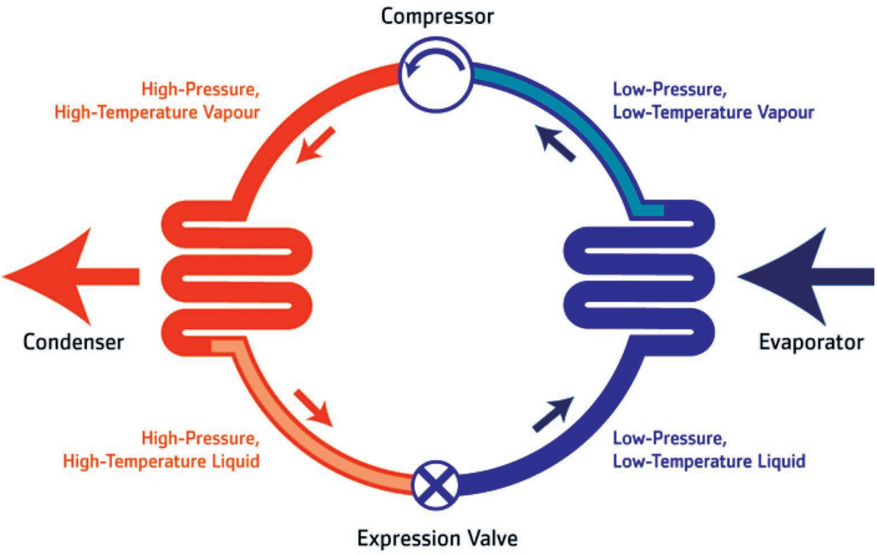


Figure 11.1. The Scheme of the Heat Pump

This technology can be described using an ordinary household refrigerator. This device consists of two heat exchangers (condenser and evaporator) and a compressor. The units are combined into a common contour. The circuit is filled with refrigerant, for example freon, which has a sufficiently low boiling point, about 20°C.

Passing through the evaporator, it changes from a liquid state to a gas at low pressure and low temperature.

Thus, the heat pump has a Carnot machine, that works in the opposite direction. Such a refrigerator pumps heat from the cooled volume to the ambient air. If you place the refrigerator on the street, then, pulling the heat out of the outside air and transferring it inside the house, you can easily heat the room.

Application of heat pumps in other countries. The European Union, China and Japan encourage the use of heat pumps. In Sweden, Spain, the United Kingdom and China, the program for obtaining subsidies for the installation of this equipment is working effectively. In France, the population has the opportunity to apply for a tax credit for energy conservation and use of renewable energy sources. The national energy consumption standards of Germany put forward stringent requirements for the energy efficiency of buildings, and this actually motivates the use of low-temperature heating systems. The European Union has also introduced a Directive on building energy performance to improve the energy efficiency of buildings, and as a result, heat pumps account for about a quarter of the total European market for appliances intended for space heating.

11.3. Potential of Geothermal Energy of Ukraine

Ukraine has significant resources of geothermal energy, whose total potential in the program of state support for the development of non-traditional and renewable energy sources and small hydro and heat energy is estimated at 438,109 kWh per year, which is equivalent to fuel reserves of 50-106 tons of s.f.

Ukraine is abundant in geothermal energy resources. Areas from low to medium-grade thermal reservoirs are very common. In some regions territories of different resources range were determined correctly, but for other ones we have no enough thermal data to draw a resource map.

One of the promising areas for the development of geothermal power is the creation of combined energy technology units for generating electricity, heat and valuable components contained in geothermal coolants.

Geothermal plants need very small areas, much smaller than those needed for other types of power plants. They can be located on virtually any land, including agricultural land. If only 1% of the geothermal energy of the earth's crust (10 km deep) could be used, we would have the amount of energy 500 times greater than all the world's oil and gas reserves. The global geothermal market is at about 13.3 GW of operating capacity as of January 2016, spread across 24 countries. In 2015, the global geothermal market was developing about 12.5 GW of planned capacity spread across 82 countries.

Based on current data, the global geothermal industry is expected to reach about 18.4 GW by 2021.

Calculations of such systems show that under certain specified operating conditions, GPP can be operated for a predetermined period without reducing the initial coolant temperature at the exit from the lifting wells. To implement the idea of creating a geo-electric power station, it is necessary that a perceptive reservoir with a sufficiently large capacity (50 m and more) existed at the field developed.

In Fig. 11.2 one of the possible variants of the principle technological scheme of GPP using a circulating system of technical water supply is shown.

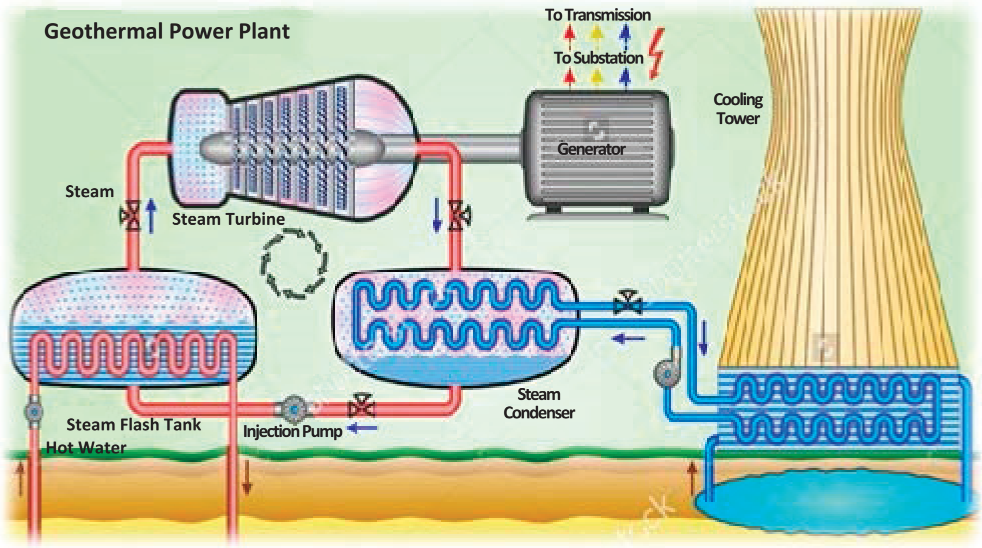


Figure 11.2. Principle Technological Scheme of GPP

1 – evaporator; 2 – turbine; 3 – generator; 4 – the condenser; 5 – water turbine; 6 – ejector; 7 – cooling tower; 8 – boreholes; 9 – gas separators; 10 – pumps

Fig. 11.3 shows a schematic diagram of a station with a two-circuit power plant on low-boiling substances block-modular construction with power installations of the Israeli company, which is recommended for use at GPP projected.

The comparison of the technical and economic indicators of the two options shows the advantages of the station variant with binary power installations, which is mainly due to the best technical performance and high performance characteristics of the Israeli equipment.

Based on the available estimates of geothermal energy reserves, the priority areas in Ukraine are the Kerch Peninsula, the Carpathian Mountains

(Lviv region), Donetsk, Zaporizhia, Lugansk, Poltava, Kharkiv, Kherson, Chernigov and other regions.

It is necessary to expect an effective use of underground energy carriers in the first place in the Carpathian region, where a large number of old oil wells remained. The total potential of the underground waters of the Carpathian and Crimean regions is 1.5 mln m^3 per day, or 550 million m^3 per year. Resources of geothermal energy by thermal equivalent in our country exceed the reserves of traditional fuel.

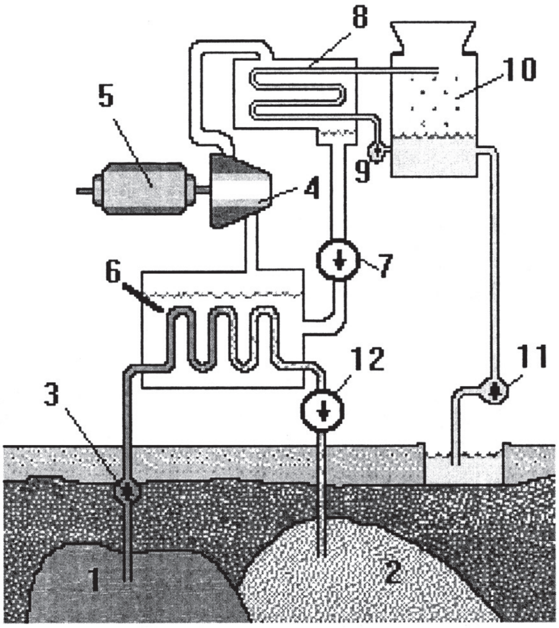


Figure 11.3. The basic technological scheme of the GPP version with binary power plants produced by ORMAT company

1 – pool of hot water 2 – zone of injection of coolant; 3 – deepened pump for pumping geothermal coolant; 4 – turbine; 5 – generator; 6 – steam generator; 7 – circulating pump; 8 – condenser; 9 – technical water supply pump; 10 – cooling tower; 11 – pump of added water; 12 – geothermal coolant injection pump

In Ukraine, six priority areas for the development of geothermal energy have been identified, providing for the creation of:

- geothermal stations for heat supply of cities, settlements and industrial facilities;
- heat supply systems with underground heat accumulators;
- drying plants;
- refrigeration plants;
- geothermal heat supply schemes for greenhouses.

Basic definitions and concepts. *Geothermal energy. Heat of the Earth. Radioactive. Geothermal gradient. Energetic resources. Primary and secondary energy resources. Hydrothermal sources. Geothermal waters. Under-ground energy carriers. Heat supply systems. Well. Thermal waters. Steam-water mixtures.*

Test questions and tasks

1. Discover the concept of geothermal energy.
2. What are the criteria for the development of geothermal power engineering?
3. How can we consider all the natural heat that is contained in the earth's crust?
4. What is the global importance of geothermal energy?
5. Which countries are actively engaged in the development of geothermal energy?
6. Explain the principle of the geothermal power plant.
7. Due to what is in possible a significant scale of development of geothermal energy in the future?
8. What are geothermal heat pumps? How do they function?
9. Describe the potential of geothermal energy in Ukraine.
10. Make your conclusions and give suggestions for the development of geothermal energy.

CHAPTER 12
OTHER TYPES OF ENERGY ALTERNATIVE SOURCES

Key issues

12.1. The Energy of the Seas and Oceans

The seas and oceans are huge accumulators and transformers of solar energy, which turns into the energy of waves, currents, heat and wind. The energy resources of the ocean are restorative and practically inexhaustible. The experience of operating already existing systems of ocean and marine energy shows that it almost does not harm the environment. The world ocean concentrates a powerful energy potential. This, first, the solar energy absorbed by ocean water, is in the energy of sea currents, waves, surf, the temperature difference of different layers of sea water and, secondly, the energy of attraction of the Moon and the Sun, which causes sea tides. This huge and environmentally friendly potential is not yet used.

Tidal energy

Tides are the result of gravitational attraction of large masses of water of the oceans by the Moon and to a lesser extent by the Sun. As the Earth rotates, part of the ocean's water rises and remains in this position for some time with gravitational attraction. At high tide, the maximum level of the rising of the water reaches the land. The further rotation of the Earth weakens the influence of the Moon on this part of the ocean, and the tributary comes. The ebb and flow are repeated twice a day, although the exact time of their onset varies depending on the season and the position of the moon.

According to the energy of the tides, it consists of the potential energy of water and the kinetic energy of the waves. According to calculations, the entire energy of the tides of the World Ocean is estimated at 1 billion kW, while the total energy of all the rivers of the globe is 850 million kW. So, the huge energy capacity of the seas and oceans is very valuable for humans.

If the Moon, the Sun and the Earth are on the same straight line, then the Sun attracts by its attraction the influence of the Moon – there is a strong influx. When the Sun is at right angles to the segment Earth-Moon (quadrature), then there comes a weak inflow (small water). The period of change in strong and weak tides is seven days. However, the movement of tides is affected by the movement of celestial bodies, the nature of the coastline, the depth of the water, sea currents and wind. The average height of the tide is only 0.5 m, except for cases when the water masses move in relatively narrow limits. Then the wave height can be 10-20 times higher than the normal height of the supply air.

The highest and strongest tidal waves occur in small and narrow bays or estuaries of rivers flowing into the seas and oceans. For example, the tidal wave of the Indian Ocean goes against the Ganges current for a distance of 250 km from its mouth. The tidal wave of the Atlantic Ocean rises 900 km up the Amazon. In closed seas, such as the Black or the Mediterranean, small tidal waves arise. The most suitable for the use of energy potential are those parts of the sea coast where the tides have a large amplitude, and the contour and relief of the shore allow the construction of large enclosed "pools".

Already in the Middle Ages, the energy of the tides was applied for practical purposes. The first facilities, the mechanisms of which were powered by supply energy, were mills and sawmills that appeared in the 10th-11th centuries on the shores of England and France. The rhythm of the work of these mills was intermittent, which is permissible for primitive structures, performing simple but useful functions for their time. For modern industrial production, it is not very suitable, so the energy of the tides was used to obtain a more convenient electric power. But for this it was necessary to create on the shores of the oceans and seas tidal power plants (TPP). The first marine PES power of 635 kW was built in 1913 in the Bay of Liverpool (England).

The construction of TPP is associated with great difficulties. First of all, the energy depends on the nature of the tides, which can not be influenced, because they are determined by astronomical factors. Despite this, the work on developing TPP continues – today, about 300 different technical projects for their construction have been proposed. However, not all regions of the globe have conditions for such construction. Studies have shown that the transfer of tidal electricity from the coastal zone to the central parts of the continents will be justified only for certain areas of Western Europe, the United States, Canada, and South America. So, in the tides, replacing each other twice a day, there is a huge energy that can theoretically be used without technical problems, but such large-scale projects are associated with high capital costs, as well as the impulsive nature of obtaining large amounts of electricity in remote areas from consumers.

A simple power plant is a dam with turbines across the mouth of the bay, but it can cause environmental degradation. As already noted, power plants that use the energy of the sea tides are beneficial to build on the sections of the coast of the World Ocean, where the tides are high. These areas include, for example, the Canadian Bay of Fundy (17 m high), the English Channel (15 m), the Penzhina Bay of the Sea of Okhotsk (13 m), etc. The entire thickness of the ocean tides on the planet is estimated at 3000 GW. Of these, approximately 1,000 GW are dispersed in shallow coastal areas where engineering facilities can be built.

Now TPP have been built and for 20-25 years they have successfully worked on three continents: the industrial Rana on the coast of the English Channel (240 MW), the experienced ones Kislogubskaya in the Kola Bay (Russia) with a capacity of 400 kW, Jiangxiang with a capacity of 3.2 MW (China)) And Annapolis with a capacity of 20 MW (Canada).

In Japan, for example, TPP operates according to the following scheme: at night, when electricity consumption is low, the inflow raises seawater into a special reservoir, and in the daytime this water merges back, generating electricity. For Japan with its long coastline to find suitable places for the construction of such TPP is easy. In this country, 53 atomic (that is, potentially dangerous) power plants operate today, and it has to import fossil fuels. Therefore, the construction of TPP for Japan is both economically viable and environmentally very important. In the process of building a tidal power plant, much attention is paid to the ecological compatibility of the structure. To do this, the shape of the bottom of the channels through which the seawater flows is selected so that the animals that accidentally get to the channel, could get out of it.

In general, during the construction of a TPP on the river, a dam is built to delay high tide waters. When the incoming water retreats, the dam water is released into the ocean through pear-shaped turbines under the dam, and electricity is generated. Electricity can be produced both at low tide and at high tide. The tidal wave is delayed by the dam as a result of the opening of a number of bottom gates, which allows it to move upstream along the river in the direction of the source. The closures are closed when the tide reaches the highest level, and then, as far as the outflow, the water locked behind the dam is allowed to drain to the sea through the turbines. At a low water level, that is, at low tide, most of this water descends. When the incoming water comes back, they stop before the closed gates, the water level from the sea side exceeds its level on the side of the dam facing the land. Once sufficient head is reached, the water is allowed to flow up the river, passing through the turbines, and again generate electricity. Thus, energy is produced both from the outflow, and from the inflow.

Some TPP use a new technology. In the last phase of the inflow, the difference in water levels in the reservoir behind the dam and in the ocean can be about two meters. At this time, electricity from some other source can be used to pump ocean water (using turbines) into the tidal pool. Water is pumped to a height of only a few dozen centimeters, so much energy is not required. When the tidal wave recedes, this additional water falls from a height of 6-10 m, producing much more electricity than it was spent. And the idea itself is realized at low tide, but in this case the water is pumped out from the supply pool into the ocean.

While for the high cost of these facilities, the governments of the countries are not inclined to invest in supply energy, because such stations are 2-2.5 times more expensive than river hydroelectric power stations with the same, average volume of produced energy (primarily through additional costs for protective jumpers in front of and behind the object). But if the initial investment is made, energy production no longer requires any fuel. Only the maintenance of the system is needed, so the cost of energy remains low. In addition to the cost of building the station, there are other negative aspects in tidal energy. If TPP is located far from the nearest large energy consumer, long and expensive transmission lines will be required, but such transmission over long distances becomes more common as new efficient lines are created.

Finally, it is worth mentioning another negative feature of tidal energy – its impermanence. In the normal operation of tidal energy, electricity is produced only at the beginning of the ebb, that is, when the level of water accumulated in the basin is sufficiently higher than its level in the sea. As the water level in the basin decreases, electricity production decreases and around the low point the tide drops to zero, as the level difference disappears. If the TPP is equipped with reversible turbines, then energy can be generated through the inflow, which occurs, but only after the inflow level sufficiently exceeds the water level behind the dam. When the tide reaches its maximum height, the energy production again approaches zero. Thus, the energy production curve then rises, then falls twice a day in accordance with two supply cycles.

Such cyclic energy production is unlikely to meet the daily needs in it. Peak demand and peak production may sometimes coincide, since the time of both tides shifts as the season changes, but most often there will not be such a coincidence. Therefore, the supply of energy to the network must be regulated in some way. This means that the generation of energy by other stations must of course decrease when the rate of supply to the output reaches a maximum, and, conversely, grows when it falls. In fact, energy from PES fairly regularly replaces the energy produced by other means, thus saving coal, etc.

It is worth mentioning also some physical and biological consequences of the construction of TPP. Physical consequences are manifested after the impact on the natural environment of tidal pools, when from the sea on the TPP there are certain physical changes. Even if the amplitude of the inflow increases by only 30 cm, this can lead to the intrusion of seawater into coastal wells and create a threat to buildings located near upper tide mark. It is also possible to accelerate coastal erosion, and lowland areas, including roads, that will be flooded when storms and tides operate simultaneously. The coastline will become almost unusable due to higher tides.

Of course, the loss of the coastal area, can be destroyed through an inunda-tion (estimated from 15 to 40 km^2), depends on the steepness of the slope and the nature of the shoreline. A tide, lower by 15 cm, is able to impede access to boats and to water from the docks. The increased altitude of the tide can cause more saline water to enter the mouth of the rivers and thereby change the living conditions of aquatic organisms. With the increase in the amplitude of the tides, strong tidal currents will appear, which can lead to the erosion of sandbanks and sand filling of existing navigable hoses, and will complicate the passage of ships.

Biological consequences

The construction of a large TPP affect the important biological space along the ocean coast. This band is called the inflow zone and extends from the point of the highest tide to the lowest point, becomes visible at low tide (both these limits are slightly shifted with a change of season). In this zone on the sandy shores live different organisms: crabs, shrimps, worms and some bivalve mollusks, and on rocky – organisms attached to rocks (mussels, oysters, sea acorns, large algae). In the water of the tidal zone lives phytoplankton – diatom algae, which move with the water of the tides. The supply energy is able to change the stable balance between species, formations of the supply zone.

The emergence of TPP can not only affect local groups, but also harm migratory species that will pass through the turbines of the power plant. To prevent this, grids can be used, the suitability of staircases remains in question. Migratory birds feeding on salt marches, such as coast and plover, are likely to find less food in a tidal basin with a power plant, as organisms will perish when passing through a turbine. So far, there are many unexplored issues related to the biological consequences of the impact of TPP on nature.

So, in spite of the fact that places where tides could be used for power generation, energy conversion to TPP has significant drawbacks:

– non-coincidence of the main periods of the occurrence of tides associated with the movement of the Moon, with the usual period of a sunny day for a person;

– change in the height of the tide and the power of the tidal current with a period of two weeks, which leads to a fluctuation in the production of energy;

– the need to create high-flow water flows with a relatively small difference in altitude, makes use of a large number of turbines operating in parallel;

– large capital expenditures for the construction of TPP;

– Potential environmental violations, changes in estuary and marine areas.

Energy of sea waves

The energy of the sea waves is the kinetic energy that is carried by the vibrations of the sea surface under the influence of the wind. With the help of wave transformers, wave energy is realized in electric or other, suitable for use. According to the US researchers, the total energy capacity of the World Ocean is 90 billion kW. And the average wave height of 3 m carries about 100 kW of energy per 1 m^2 of the coast.

The idea of generating electricity from sea waves was developed by a 1935 Soviet scientist K. Tsiolkovsky. One of the first power plants that was using the energy of sea waves was built in 1970 near the Norwegian city of Bergen. It had a power of 350 kW and provided energy to a village of hundreds of houses. The possibility of creating more powerful wave stations is being investigated by scientists from the United Kingdom, the United States and Japan.

So far, some progress has been made in the use of sea-wave energy for electricity generation. Wave power plants are used to power beacons, buoys, signal sea lights, stationary oceanological instruments located far from the coast. Compared to conventional electric accumulators, batteries and other current sources, they are cheaper, safer and require less maintenance. On experimental power plants, even small waves of 35 cm height force the turbine to develop a speed of more than 2 thousand revolutions per minute.

In Japan, since 1978, there is a floating power station that uses the energy of sea waves. The station allows to receive and convert the energy of waves in the chambers of the compressor type to the energy of compressed air. Then the turbine blades rotate the electric generator. Today in the world, about 400 beacons and navigation buoys are fed by wave power plants. The wave generator is successfully operated on the floating lighthouse of the port of Madras in India. In Norway since 1985, operates the world's first industrial wave station with a capacity of 850 kW. Power plants of this type are cost-effective for small settlements on the ocean coast.

In recent years, many different technical projects have appeared. So in the UK power engineers designed an aggregate, that produces electricity from the shock waves. According to the designers, 10 such units installed at a depth of 10 m off the western coast of the UK can be provided with electricity a city with a population of 300 thousand people. The British Isles have a long coastline, and in many places the sea remains turbulent for a long time. One of the projects of using sea waves is based on the principle of water column, fluctuates. In giant "boxes" without a bottom and with holes at the top under the influence of waves, the water level rises or falls. The water column acts like a piston: sucks in air and pumps it into the turbine blades. The main difficulty is the coordination of inertia of turbine wheels with the amount of air in the boxes so that due to inertia the speed of rotation of the turbine shafts remains constant in a wide range of conditions on the sea surface.

Today, the UK is building the world's largest wave power plant, where it is planned to test several technologies for converting wave energy into electric current. Despite the status of the demonstration, the station will have a capacity of 20 MW. The multi-million dollar project, financed by the UK government, European foundations and industrial companies, provides an unusual scheme: 1x2 km of sea areas will be leased to industrial companies. In these areas, sets of wave generators of various schemes will be installed, which will be combined with the shore.

A wide range of possibilities of wave energy complexes (WEC). WEC of various capacities can be used for power supply of coastal and island settlements, as well as sea vessels. On the basis of low-power WEC, it is possible to create meteorological systems, global and regional communication and navigation systems, telecommunications systems, as well as installation of emergency personal life support equipment and the like. Powerful multi-module WEC can be a reliable energy base for creating environmentally friendly objects of the marine and coastal processing industry. Such facilities provide an opportunity to process seafood, desalinate water, organize chemical production based on the electrolysis of sea water, and also use electrosynthesis to produce monomers and polymers.

The energy produced by WEC can be used not only directly by processing and production facilities, but also accumulated with the help of various accumulation devices. Very promising is the use of powerful multi-module WEC for large-scale electrolysis production of hydrogen, oxygen and ozone. The use of electrolysis of seawater interiors for the production of hydrogen is much more promising from the current widespread technology based on the conversion of hydrocarbons or petroleum products, the reserves of which are rapidly declining.

WEC capacity of several megawatts are operated in many countries, and they are multifunctional, since they produce electric energy; heat energy; clean drinking water; compressed air; hydrogen; oxygen various chemicals.

For many enterprises in the processing industry (agricultural products, seafood) WEC play a big role. Agricultural enterprises and recreation areas are especially interested, because WECs have significant advantages:

– the possibility of placing WEC close to the consumer;

– operative possibility of consumption and sale of the produced energy goods (electricity, heat, oxygen, hydrogen, etc.);

– high quality of electric power (stability of frequency, voltage and shape of a sinusoid) stability of the technological process in production, where energy is used;

– independence of the consumer from a centralized energy supplier.

While wave energy is not very intensive, the energy of waves is difficult to master in comparison with the wind. Serious work in this direction is carried out only the last 20 years, and it will take another 10 years to compete with wind generators. Waves can be used along the densely populated western coast of Europe, USA, Chile, Australia, New Zealand. Due to the local use of such energy, it is possible to cover almost half of the world's electricity demand. Further from the coast it can be produced in large quantities, although the creation of a generator network will in this case be more expensive. But the potential of ocean energy can surpass all other resources combined.

The advantages of wave energy are that it is sufficiently concentrated, available for conversion and for any time interval can be predicted depending on the weather conditions. Formed by the action of the wind, the waves retain their energy potential well, spreading over considerable distances. At the modern level of scientific and technological development, and even more so in the future, attention to the problem of using the energy of sea waves will undoubtedly make it an important component of the energy potential of the maritime countries.

The energy of the difference in salinity

The salty water of the oceans and seas has huge undiscovered energy reserves, which can be efficiently converted to other forms of energy in areas with large salinity gradients.

The osmotic pressure arising from the mixing of fresh river waters with saline is proportional to the difference in the concentrations of the salts of these waters. As a source of osmotic energy suggest using salt domes in the thickness of the ocean floor. Calculations showed that energy can be obtained by dissolving the salt of the average salt-oil dome by at least as much as using the oil contained in this dome. Projects on the transformation of "salt" energy into electrical are being developed.

Thermal energy

The world ocean is a huge natural collector of solar radiation. The temperature difference between its warm surface waters, which absorb solar radiation, and the colder bottom, is up to 20-25°C. This provides a reserve of thermal energy, continuously replenishes and can theoretically be transformed into other types. The term for the conversion of the thermal energy of the ocean means the conversion of some part of this thermal energy into work and then into electrical energy. The mechanism produces energy, is driven by the temperature difference between cold water raised from the depth, and hot water collected from the surface.

The working fluid circulates in a closed circuit, it removes heat from hot water in the heat exchanger, in the vapor phase drives the turbine connected to the generator and then condenses in a condenser that is cooled by cold water. This concludes the cycle.

In 1979 near the Hawaiian Islands, the first thermal power plant of mini-OTES began operating. The trial operation of the plant for 3.5 months showed suf-ficient reliability and efficiency, its total power averaged 48.7 kW. The installa-tion gave 12-15 kW of energy to the external network to charge the batteries, and the rest was spent for own needs. That is, for the first time in the history of technology, the installation of the mini-OTES was able to supply the external environment with useful power, while also covering its own needs. The experi-ence gained with the operation of the mini-OTES, gave impetus to the design of powerful systems of this type.

In the ocean, layers of water with different temperatures are sometimes quite close. The greatest (up to 20-25°C) temperature difference is in the tropical zone of the World Ocean. This is the basis of the principle of obtaining electricity. In a special heat exchanger, pumped cold deep water pumps and heated by the Sun surface. The working agent (freon), as in a home refrigerator, alternately evaporates and becomes liquid in various parts of the heat exchanger. A pair of freon moves the turbine of the generator. Now such an installation with a capacity of 100 kW operates on the Pacific island of Nauru, providing the energy needs of the population of this island. In Hawaii, a test of a 50 kW installed on the ship was started. If the energy efficiency of the temperature difference is at least 1%, the potential of the thermal energy of the ocean will exceed the potential of all fuel minerals.

In addition, the inexhaustible reserves of the kinetic energy of the sea currents, accumulated in the oceans and seas, can be converted into mechanical and electrical energy by means of turbines immersed in water (like windmills immersed in the atmosphere).

Thus, the energy of the seas and oceans encompasses the energy of currents throughout the world's oceans, the energy of tides, waves, mixing of fresh and salt sea water, the energy of temperature gradients between surface and deep layers of water in the tropical regions of the ocean, and the like. The technical realization of the use of these sources is possible under the following conditions:

– mastering only the most powerful currents;
– presence of tides with increased amplitude;
– the presence of wave energy sufficient for use;
– the presence of ocean areas with a significant difference in salinity between river runoff and sea water with a temperature difference of at least 20°C.

Thus, the use of the energy of the World Ocean for the generation of electricity through the supply, wave and other stations has a minimal negative impact on the regime of water and the shoreline. In addition, they will give a positive, albeit local, effect of reducing the mechanical impact of the ocean on the coastal strip, and also reduce the tendency for an increase in temperature in the surface layer of the atmosphere.

12.2. Hydrogen Energy

The aggravation of the problem of environmental protection against the background of the growing demand for fuel and energy prompts the world community to look for new energy technologies that can provide an acceptable level of pollution without slowing economic growth. A key place in solving this problem, according to many experts, will be hydrogen energy – the production of hydrogen and its use with fuel cells in industry, construction, energy, transport, housing and utilities and other spheres of the economy.

Hydrogen energy is considered by many specialists precisely as a means to achieve the goals of the global energy revolution, therefore, in the developed countries of the world it pays much attention, considerable funds are allocated for the development and introduction of its technologies. These works are most dynamic in CIPA, Canada, Japan, the EU countries, where, along with a significant amount of scientific research, active work is being done to com-mercialize hydrogen energy. Around the world, a number of fuel cell power plants with a capacity of several watts to megawatt have been launched, which are already competitive with plants using traditional technologies. In many countries, relevant long-term programs have been developed and are being implemented, and large funds are being allocated for their implementation. In particular, in the US for the purpose of hydrogen energy is allocated up to $ 1 billion a year. Recently, among most European countries, it was observed a rapid increase in activity in the field of hydrogen energy and in the devel-opment of fuel cells.

Concerning the technology of hydrogen production, it should be noted that it is a secondary energy carrier and is found in nature only in the form of various compounds. But the resource base for obtaining it is quite wide. In addition to water, from which hydrogen can be obtained by electrolysis using electrical and thermal energy, almost all fossil fuels, various types of biomass, as well as various waste products, domestic waste, etc., belong to the resource base.

Most famous technologies for hydrogen production are based on chemical, heat engineering processes and electrolysis of water, but their main disadvantages are the use of high-potential energy with the costs of fossil fuels and with correspondingly significant pollution of the environment. A drawback of water electrolysis is a significant level of electricity consumption. Electrolytic hydrogen is the most affordable, but also an expensive product. Today, the world's most widely used technology is the production of hydrogen or a mixture of hydrogen with other gases by steam conversion of natural gas – methane, but almost half of the initial volume of gas is spent on carrying out the endothermic process of steam conversion. In this regard, currently in the world is an intensive search for other technologies for obtaining hydrogen, able to meet the requirements of economic and energy efficiency and environmental purity.

For the production of hydrogen, it is advantageous to use the thermal and electrical energy produced by the nuclear power plant in the so-called failure mode, that is, at night, when the level of ordinary energy consumption falls.

Prospective is the electrolysis of water in combination with non-traditional renewable energy sources (solar, wind). One of the promising technologies for the production of hydrogen is the use of high-temperature helium reactors (HTHR), which are developed as part of an international project to build a safe nuclear reactor GT MGR (Russia, USA, France).

In addition to hydrogen production, the problematic issue is the creation of an economical and reliable hydrogen storage system. In this issue, gas-cylinder, cryogenic and metal-hydride storage methods are considered promising. The final choice of the method of storage requires additional scientific research and expertise.

The most promising direction of using hydrogen energy is the replacement of hydrocarbon fuels with hydrogen in transportation systems, primarily in the automotive industry (internal combustion engines). Other areas of application of hydrogen and mixed gas containing hydrogen can be chemical, oil refining, metallurgy, food industry, housing and communal services. A wide application in the world is acquired by fuel cells for decentralized stationary energy and for motor vehicles.

In Ukraine, research in the field of hydrogen technologies is at an early stage, despite the fact that they have been conducted for a long time. Below are listed the main factors hindering the activation of the work on hydrogen energy in Ukraine: the lack of a strategy for the development of hydrogen energy as the energy of the future, the national program for the development and production of hydrogen fuel cells and power plants based on them, as well as the relevant legislative framework, and applied research and development in the field of hydrogen energy; balanced state policy and real support of works on environmentally friendly resource and energy-saving technologies; the unpreparedness of private business to subsidize fundamental and applied research.

The undoubted advantage of hydrogen energy for Ukraine could be the possibility of significantly reducing the country's energy dependence by transforming its own energy resources (coal, peat, shale, biomass, industrial waste, etc.) into hydrogen, with its subsequent use to meet the country's energy needs.

Basic definitions and concepts. *Energy of the tides. Tidal power plants. Energy of sea waves. The difference is salinity. Thermal energy of the seas. Hydrogen energy. Thermochemical processes. Electrolysis of water.*

Test questions and tasks

1. What are the ways of using the energy of the seas and oceans.
2. What is the basis for the operation of tidal power plants?
3. What are the advantages and disadvantages of using tidal power plants.
4. Describe the possibilities of using the energy of sea waves.
5. What are the characteristics of the application of energy differences in salinity of water?
6. What is the effectiveness of the application of the thermal energy of the seas?
7. In which countries are the installations that convert the thermal energy of the ocean into electricity?
8. What is hydrogen energy?
9. What is the most promising direction of using hydrogen energy?
10. List the main factors hindering the activation of work on hydrogen energy in Ukraine.

Biofuel Glossary

Absorption	A process by which a substance incorporated in one state is transferred into another substance of a different state
Acid	A solution that has an excess of hydrogen ions (H+).
Adsorption	A process by which molecules of a substance from a gas mixture or liquid solution became attached to a solid or liquid surface
Alcohol	An alcohol is an organic compound with a carbon bound to a hydroxyl group. Examples are methanol, CH3OH, and ethanol, CH3CH2OH.
Alternative energy	A term used for an energy source that is an alternative to using fossil fuels. Generally, it indicates energies that are non-traditional and have low environmental impact. The term alternative is used to contrast with fossil fuels according to some sources. By most definitions alternative energy doesn't harm the environment, a distinction which separates it from renewable energy which may or may not have significant environmental impact.
Aromatic	A chemical that has a benzene ring in its molecular structure (benzene, toluene, xylene). Aromatic compounds have strong, characteristic odors.
Azeotrope	A mixture that exhibits the same concentration in the vapor phase and the liquid phase
B20	A mixture of 20% biodiesel and 80% petroleum diesel based on volume.
Bacteria	A small single-cell organism. Bacteria do not have an organized nucleus, but they do have a cell membrane and protective cell wall. Bacteria can be used to ferment sugars to ethanol.
Base	A solution that has an excess of hydroxide ions (OH-) in aqueous solution.

Benzene	An aromatic component of gasoline, which is a known cancer-causing agent.
Biodiesel	Fuel made from plant oils that can be used in diesel engines. It is typically made of renewable organic feedstock such as soybean or rapeseed oils, animal fats, waste vegetable oils or microalgae oils.
Biodiesel	A biodegradable transportation fuel for use in diesel engines that is produced through the transesterfication of organically- derived oils or fats. It may be used either as a replacement for or as a component of diesel fuel.
Biofuels	Biomass converted to liquid or gaseous fuels such as ethanol, methanol, methane, and hydrogen.
Biomass	Renewable organic matter, and can include biological material derived from living, or recently living organisms, such as wood, waste, and alcohol fuels.
Biomass	An energy resource derived from organic matter. These include wood, agricultural waste and other living-cell material that can be burned to produce heat energy. They also include algae, sewage and other organic substances that may be used to make energy through chemical processes.
By-product	Material, other than the principal product, generated as a consequence of an industrial process or as a breakdown product in a living system.
Carbohydrate	A class of organic compounds including sugars and starches. The name comes from the fact that many (but not all) carbohydrates have the basic formula CH20.
Carbon dioxide	(C02) A colorless, odorless gas produced by respiration and combustion of carbon-containing fuels. Plants use it as a food in the photosynthesis process.
Carbon monoxide	(CO) A colorless, odorless, poisonous gas produced by incomplete combustion.
Catalyst	A substance that increases the rate of a chemical reaction, without being consumed or produced by the reaction. Enzymes are catalysts for many biochemical reactions.

Celluiase	A family of enzymes that break down cellulose into glucose molecules.
Cellulose	A carbohydrate that is the principal component of wood. It is made of linked glucose molecules that strengthens the cell walls of most plants.
Combustion	A chemical reaction between a fuel and oxygen that produces heat (and usually, light).
E-10	A mixture of 10% ethanol and 90% gasoline based on volume.
E-85	A mixture of 85% ethanol and 15% gasoline based on volume.
Energy crop	A crop grown specifically for its fuel value. These include food crops such as corn and sugarcane, and non-food crops such as poplar trees and switchgrass.
Enzyme	A protein or protein-based molecule that speeds up chemical reactions occurring in living things. Enzymes act as catalysts for a single reaction, converting a specific set of reactants into specific products.
Ester	An ester is a compound formed from the reaction between an acid and an alcohol. In esters of carboxylic acids, the -COOH group of the acid and the -OH group of the alcohol lose a water and become a -COO- linkage.
Ethanol	(CH3CH2OH) A colorless, flammable liquid produced by fermentation of sugars. Ethanol is used as a fuel oxygenate. Ethanol is the alcohol found in alcoholic beverages.
Fatty acid	A fatty acid is a carboxylic acid (an acid with a -COOH group) with long hydrocarbon side chains.
Fermentation	A biochemical reaction that breaks down complex organic molecules (such as carbohydrates) into simpler materials (such as ethanol, carbon dioxide, and water). Bacteria or yeasts can ferment sugars to ethanol.
Fossil fuel	A carbon or hydrocarbon fuel formed in the ground from the remains of dead plants and animals. It takes millions of years to form fossil fuels. Oil, natural gas, and coal are fossil fuels.

Fungi	Fungi are plant-like organisms with cells with distinct nuclei surrounded by nuclear membranes, incapable of photosynthesis. Fungi are decomposers of waste organisms and exist as yeast, mold, or mildew.
Global warming	A term used to describe the increase in average global temperatures due to the greenhouse effect. Scientists generally agree that the Earth's surface has warmed by about 1 degree Fahrenheit in the past 140 years.
Glucose	(C6H1206) A six-carbon fermentable sugar.
Glycerin	(C3H803) A liquid by-product of biodiesel production. Glycerin is used in the manufacture of dynamite, cosmetics, liquid soaps, inks, and lubricants.
Greenhouse effect	The heat effect due to the trapping of the sun's radiant energy, so that it cannot be reradiated. In the earth's atmosphere, the radiant energy is trapped by greenhouse gases produced from both natural and human sources.
Greenhouse gas	A gas, such as water vapor, carbon dioxide, tropospheric ozone, methane, and low level ozone, which contributes to the greenhouse effect.
Hydrocarbon (HC)	An organic compound that contains only hydrogen and carbon. In vehicle emissions, these are usually vapors created from incomplete combustion or from vaporization of liquid gasoline. Emissions of hydrocarbons contribute to ground level ozone.
Hydrolysis	A chemical reaction that releases sugars, which are normally linked together in complex chains. In ethanol production, hydrolysis reactions are used to break down the cellulose and hemicellulose in the biomass.
Municipal solid waste	Any organic matter, including sewage, industrial, and commercial wastes, from municipal waste collection systems. Municipal waste does not include agricultural and wood wastes or residues.
Nitrogen oxides (nox)	A product of photochemical reactions of nitric oxide in ambient air, and the major component of photochemical smog.

Non-renewable resource	A non-renewable energy resource is one that cannot be replaced as it is used. Although fossil fuels, like coal and oil, are in fact fossilized biomass resources, they form at such a slow rate that, in practice, they are non-renewable.
Organic compound	An organic compound contains carbon chemically bound to hydrogen. Organic compounds often contain other elements (particularly O, N, halogens, or S).
Oxygenate	An oxygenate is a compound which contains oxygen in its molecular structure. Ethanol and biodiesel act as oxygenates when they are blended with conventional fuels. Oxygenated fuel improves combustion efficiency and reduces tailpipe emissions of CO.
Ozone	A compound that is formed when oxygen and other compounds react in sunlight. In the upper atmosphere, ozone protects the earth from the sun's ultraviolet rays. Though beneficial in the upper atmosphere, at ground level, ozone is called photochemical smog, and is a respiratory irritant and considered a pollutant.
Particulates	A fine liquid or solid particle such as dust, smoke, mist, fumes, or smog, found in air or emissions.
Petroleum	Any petroleum-based substance comprising a complex blend of hydrocarbons derived from crude oil through the process of separation, conversion, upgrading, and finishing, including motor fuel, jet oil, lubricants, petroleum solvents, and used oil.
Photosynthesis	A complex process used by many plants and bacteria to build carbohydrates from carbon dioxide and water, using energy derived from light. Photosynthesis is the key initial step in the growth of biomass and is depicted by the equation.
Polymer	A large molecule made by linking smaller molecules ("monomers") together.
Polysaccharide	A carbohydrate consisting of a large number of linked simple sugar, or monosaccharide, units. Examples of polysaccharides are cellulose and starch.

Reaction	A chemical reaction is a dissociation, recombination, or rearrangement of atoms.
Renewable energy	Energy that is generated from natural processes that are continuously replenished. This includes sunlight, geothermal heat, wind, tides, water, and various forms of biomass. This energy cannot be exhausted and is constantly renewed.
Renewable energy resource	An energy resource that can be replaced as it is used. Renewable energy resources include solar, wind, geothermal, hydro and biomass. Municipal solid waste (MSW) is also considered to be a renewable energy resource.
Starch	A molecule composed of long chains of glucose molecules. Many plants store the energy produced in the photosynthesis process in the form of starch.
Toxics	As defined in the 1990 Clean Air Act Amendments, toxics include benzene, 1,3 butadiene, formaldehyde, acetaldehyde, and polycyclic organic matter.
Transesterification	A chemical process which reacts an alcohol with the triglycerides contained in vegetable oils and animal fats to produce biodiesel and glycerin.
Triglyceride	A triglyceride is an ester of glycerol and three fatty acids. Most animal fats are composed primarily of triglycerides.
Volatile	A solid or liquid material that easily vaporizes.
Yeast	Any of various single-cell fungi capable of fermenting carbohydrates.

List of Illustrations

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