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The main goal of this thesis is to show the possibility of Kazakhstan in the production of bioethanol. Also the task is to create and analyses the theoretical production of bioethanol. The whole thesis is divided into three main parts. The first part reviewed the situation in Kazakhstan with waste and alternative energy sources, in particular biofuel. The second part described the production of ethanol; it reviewed in brief the main processes and parameters. The third part, the final one, is practical. In the practical part, a theoretical model of production is created, an analysis of mass balance and economic balance are carried out. As a result, a theoretical model was created that could show the possibility of production in a given country.

Keywords: PFD, mass balance, stream, LHW, straw.

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Declaration

I confirm that the masters‘s thesis was disposed by myself and independently, under leading of my thesis supervisor. I stated all sources of the documents and literature.

In Prague………………………… …………………………

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1 Theoretical part

1.1 Introduction

Every day people are finding the problems with wastes. The storage of garbage carries a big problem for the environment, since waste has various physical and chemical properties that are hazardous to life and ecology. A large amount of waste makes people find new methods for storing, transporting, sorting, recycling, etc. Many wastes have substances, pathogens, toxins and explosives materials. For these reasons, states have to be more serious about the problem of garbage. In our time, a large number of countries are concerned with the problem of environmental pollution. In this regard, these countries have the necessary laws for the storage and recycling of hazardous waste.

1.1.1 Waste in Kazakhstan

Kazakhstan is a state in the center of Eurasia, most of the territory lies on the territory of Asia and a small piece in Europe. The population of Kazakhstan is 18 million people (January 1, 2018). The area is 27 249 02 km^2. Kazakhstan is one of the largest countries, ranking 9th out of the top 10 countries. The capital city is Astana, but the largest city is Alma-Ata. The state language is Kazakh and Russian. [1]

Kazakhstan was get independence in 1991, from that period we have accumulated 43 billion tons of wastes and only 5 percent is recycled. The main problem for waste processing plant is that there is no culture of separation of garbage. If people continue just store garbage to landfills, our descendants will not have place for building houses: the area has a property to terminate, and some waste, for example polyethylene, begins to decompose only after centuries. [2]

For now according Department of Waste Management said that Kazakhstan produce 1 billion ton of wastes for each year. The country is downing in wastes. Another important problem, according to the Director of the Department of Waste Management, is the big number of garbage dumps. So, according to official data, only 14% of polygons have permits. It should also be noted that in 2015 Kazakhstan ranked second place in terms of the stocks of waste containing persistent organic pollutants among European countries, second only to Russia. [3]

1.1.2 Utilization

In Kazakhstan, the waste processing industry is practically not developed. Since on the way to processing companies face a number of financial and organizational constraints. For example, in the city of Pavlodar (which is located in the north-eastern part of Kazakhstan) there are enterprises that successfully process 96% of the waste. The main raw materials used by these enterprises are bauxite slime JSC "Aluminum of Kazakhstan" and ash waste Pavlodar TPP-1, caused by the burning of coal Ekibastuz with high ash content. The plant produces a variety of construction materials based on raw materials. In one year, the plant is capable of processing 32 000 tons of slurry and 38 000 tons of ash. However, it cannot operate at full capacity because there is no normal working capital. The percentage of utilization of industrial waste in Pavlodar is 2%. It can be said that in this area (city) a good growth of waste processing has been achieved. However, still large amounts of debris continue to be digested or simply discarded. This is largely due to the lack of efficient and economical processing technologies. A small part of waste is used in production and construction technologies in Ispat-Karmet JSC (Karaganda region), where practically all metallurgical slag is processed and used repeatedly. [4]

According to experts, there are three main options for the disposal of solid waste: the organization of landfills, incineration of waste, as well as their reuse. Each of these options has its advantages and disadvantages.

Take, for example, the processing of domestic garbage at incineration plants. On the one hand, this is environmentally unsafe, as the gaseous emissions of such plants pollute the atmosphere. In addition, burning garbage is in itself an expensive pleasure. On the other hand, there is a benefit: as a result of burning household rubbish, a large amount of ash accumulates. Organic residues after composting can serve as raw materials for the production of fertilizers and animal feed, especially fish.

The problem for liquidation or recycling of household garbage is plastic, from which produce packaging, details of household appliances, cars, design of premises. Most of the currently produced plastic is not decomposed by microorganisms, so it can poison the environment for decades.

The problem of glass recycling is somewhat easier to solve, since its re-melting is economically viable. In Germany, most of the used glass is collected - about 1.17 million tons. Over 100 thousand tons of broken glass is imported from other countries and is melted together with its own glass container. The amount of domestic garbage is reduced by repeated use of glassware, although often it is necessary to pay for it in addition to transportation costs. In order to encourage people to take out bottles, in most European countries their collateral value rises, additional foster points are created. [5]

The problem of Kazakhstan dumps is that they simply burn the garbage. But in fact with the simultaneous burning of plastic and food waste, is formed a highly toxic substance - dioxin. It accumulates in the body, even at a small concentration it affects the central nervous system and it is not inferred. Also in the garbage can be poisonous substances, such as mercury or other heavy metals, chemical compounds that dissolve in rain and thawed waters and then enter water bodies and groundwater. [5]

1.1.3 Pollution types

1.1.3.1 Air pollution

The energy sector is a major problem through the emission of sulfur oxide, nitrogen, carbon monoxide and ash. Each year, from 1990 to 1996, from 1 to 2 million tons of toxic was emitted into the atmosphere, which is approximately 30% of the total volume of atmospheric emissions in Kazakhstan. All these emissions are a consequence of low-grade coal as the main raw material, as well as a poor system for purifying volatile harmful gases in thermal power plants. Since that period, production has been reduced, which led to a 50% reduction in pollution, but the problem is still relevant. [4]

Gaseous emissions	**1990**	**1991**	**1992**	**1994**	**1995**	**1996**	**1998**	**1999**	**2000**
Emissions of **CO2**, thousand tons	275.1			182.3	Example				113.5
Emissions of **CH4**, thousand tons	2.2			1.8					1.4
Emissions of greenhouse gases, **CO2 equivalent**	319		324.5						152.5
Emissions of **SOx** thousand tons	1.480	1.471	1.422	1.135	1.133		983	946	1080
Emissions of **NOx** thousand tons	738	319	310	241	233		159	151	162
Emissions of **CO** thousand tons	2.178	760	687	468	446		361	380	391
Total weight: Emissions of pollutants from stationary sources, million tons	4.7	4.3	4.1	3.3	3.1	2.4	2.3	2.3	2.4
Power sector contribution of Total, million tons	2.5					1.0			

Table 1: Weight of pollutants from heating and power generation enterprises, ferrous and nonferrous metallurgy and oil and gas sector [4]

1.1.3.2 Persistent organic pollutants

“Persistent organic pollutants (POPs) are a group of chemicals - industrial substances such as poly-chloride biphenyl, pesticides of the dichlorodiphenyltrichloroethane (DDT) type and harmful waste products of dioxin type - the compounds and mixtures of which have toxic properties, are resistant to decomposition and higher bioaccumulation. As a result of transboundary transfer by air and water, they settle long distances from their emission points, accumulating in water and land ecosystems.” [4]

In Kazakhstan, old production and agricultural processes are the main sources of this type of pollution. Herbicides and insecticide chemicals are the most common pesticides in Kazakhstan. However, for the last 20 years the volume of use pesticides has been reduced for 4 times. In 2000, the Customs Committee estimated that the total amount of imported organic pollutants is 5346 million kilogram. According to official data, only authorized connections are imported into Kazakhstan. [4]

1.1.3.3 Toxic waste products

In Kazakhstan, 25% of garbage from industrial wastes is toxic, at the moment there are 5 billion toxic wastes in the country. By comparison, 20 years ago, the volume of toxic waste amounted to 92 million tons, more than half of which was wastes from the metal industry. As Kazakhstan has begun to develop the mining industry, pollution with substances such as radioactive nuclides, heavy metals, etc. became a big problem for the country. Ultimately, the mining industry has accumulated 4 billion tons of waste, at the enrichment plants 1.1 billion tons of wastes have been accumulated, and the metallurgical industry has accumulated 105 million tons. [4]

1.1.3.4 Nuclear testing ground

Between 1949 and 1989, nuclear tests were conducted on the territory of the Semipalatinsk region, which is located in the north of Kazakhstan. On the territory of 10 000 km^2, 470 bombs were blown up, with a capacity of 17 400 000 tons of the equivalent of trinitrotoluene. A nuclear lake named Balapan was formed on the territory of tests, in this region the level of gamma radiation exceeds the norm by 100 times. The total area of the ecological disaster is 7 million hectares. [4]

Also in the west of Kazakhstan at the moment there are two Russian test sites for nuclear tests. In these areas, a total of 39 nuclear tests were tested.

1.1.3.5 Baikonur

Baikonur is the area where since 1957 and to this day carry out many tests connected with the launch of missiles. About 1300 space rockets for launching about 1250 spacecraft on the orbit, as well as 100 intercontinental ballistic missiles were launched from this region. In 2000, 30% of the world's space industry was connected with Baikonur. This led to major environmental problems in Kazakhstan. [4]

Administrative regions of Kazakhstan	Zone of ecological crisis mln. ha.	Zone of ecological disaster mln. ha.
Total: mln. ha.	67.5	9.59
Karaganda	23.53	3.33
Akmola Oblast	10.24	1.56
Kostanai Oblast	8.72	1.36
Aktyubinsk Oblast	7.48	1.22
East Kazakhstan	4.36	-
West Kazakhstan Oblast	4.16	0.15
Atyrau Oblast	2.71	0.19
Kyzylorda Oblast	2.5	0.33
Zhambyl	1.74	0.75
Pavlodar	1.41	0.04
Mangistau	0.65	0.06

Table 2: Total areas of polluted lands [4]

1.1.4 Alternative energy source

Alternative energy sources such as: hydropower, wind, wave, sun, hydrothermal energy, biomass and biofuel energy are poorly developed in Kazakhstan. The country has potential in alternative energy sources, but the main problem is that the most energy supply system was strongly centralized in "traditional" stations. The topic of alternative energy sources has never been brought to the forefront. However, for Kazakhstan this should be very important, because large territory introduces a large energy loss during transportation. Small alternative sources plants can solve such problems as: independence of small regions from larger ones, improvement of ecology and also better production in remote "wild" areas where minerals are extracted. [4]

1.1.4.1 Hydropower

Hydropower in Kazakhstan has a potential of 170 billion kWh per year. At the moment, the country uses only about 8 billion kWh per year. Kazakhstan plans to build a large hydroelectric power station in the next 10 years. The most promising stations are planned to be launched on the Charyn River in southern Kazakhstan, as well as on the Ili River in the south. These two stations will be able to produce 900 million kWh per year. [4]

1.1.4.2 Wind power

Wind energy has great potential in Kazakhstan due to the fact that the country is located in the "wind belt". It is estimated that the country has potential of 10 megawatts per square kilometer. According to the latest data, the average wind speed is from 5 to 7 km per second, this makes it possible to use this energy. Kazakhstan plans to install a 500-megawatt wind power station in the next 20 years. These wind farms can annually produce 1-1.5 billion kWh of energy. At the moment, there are already small wind farms in the south of the country. The best areas for this type of energy are located in the south and east of the country**.** [4]

1.1.4.3 Solar power

The potential of Kazakhstan in solar energy is significant due to climate. The amount of sun hours is 2200-2300 per year, which gives approximately 1300-1800 kWh per square meter. The main area of application of this energy is the production of hot water by using solar collectors. According to local experts, it is possible to get about 13 million Gal. of heat for supply of heat water, which will save more than 1 million tons of oil equivalent. However, at the moment, this method is at the origin stage because of its high cost. The only one way help to reduce the price of the collectors is to establish local production. Also, solar energy can be used to generate electricity, which is also good and economical for Kazakhstan, but at this stage this source is in gaining momentum. [4]

1.1.4.4 Geothermal power

In comparison with other sources of alternative energy, this source is not significant, since there are just few geothermal sources on the territory of Kazakhstan. [4]

1.1.4.5 Wave power

Because Kazakhstan has access to the Caspian Sea, the energy of the waves takes place. According to various experts, wave energy can be extremely effective for the supply of oil in the Caspian regions, and also reduce the consumption of electricity from the national grid in this region by 50-85%. [4]

1.1.4.6 Biomass

Biomass is a collection of plant and animal organisms. Therefore, a large amount of garbage can is classified as biomass because it contains a part of the animal or plant organisms. This type of waste as a municipal solid waste, biological waste, paper, medical, and forestry wastes compelling cost of the biomass. [6]

According to experts, the processing of biomass waste for biogas production produces an energy volume equal to 14-15 million tons of fuel equivalent, or 10.32 million tons of oil. Kazakhstan actively supports farmers using biogas in remote areas, as the consequence is the conservation of forest massive. In a large number of farm areas, stations for the production of biogas from manure were installed. Time has shown that the use of biogas plants, producing 15 cubic meters of biogas a day, can provide the average house with heat and food. [4]

1.1.5 Potential to produce biofuels

Biofuel is a fuel from biological raw materials, obtained, as a rule, in the process of treatment biological waste. Distinguish 3 types of biofuel: liquid biofuel (for internal combustion engines, for example, bioethanol, bio methanol, and biodiesel), solid biofuel (firewood, briquettes, fuel pellets, chips, straw, and husks) and gaseous (biogas, hydrogen).

Since 2003, demand for biofuels has started to increase in the world. Annual use of biomass in the world is equivalent to consumption of 1 million tons of oil and is comparable to the level of consumption of natural gas and coal. By types of feedstock - liquid biofuel of the first generation is made from food agricultural raw materials, the second generation - from non-food natural raw materials and the third generation - from algae and other products. The main reasons for this are an increase in oil prices, as well as the preservation of the environment. The main leaders in this sector are the EU countries, the USA and Brazil. For example, in 2010, the share of biofuels in the total energy balance in the US and the EU was about 4%, while the share of biofuels in Brazil reached a level of about 25%. Thus, it is its large-scale production that largely ensured the high and sustainable profitability of the agribusiness of Brazil, which produced biofuel from sugar cane. [7]

Bioethanol is a less dense source of energy than gasoline. Bioethanol is a leader in production and consumption in the liquid biofuel market, because the costs of its production can be reduced faster than for the production of biodiesel. The economic difference can be seen in the table below. [7]

Countries	Production cost of bioethanol	Retail price of gasoline
Brazil	0.19	1.26
USA	0.33	0.7
EU	0.55	1.4

Table 3: Comparative cost of bioethanol and gasoline prices in different countries (2007-2008) $ / L [7]

Currently, the bioethanol industry in Kazakhstan is poorly developed, although with the potential of Kazakhstan, bioethanol can partially, and in some regions completely, replaces the consumption of standard fuels derived from traditional methods. In general, the prospects for the development of production and use of bioethanol in the republic exist. This is facilitated by large volumes of organic raw materials, the simplicity of technology for obtaining and using bioethanol, as well as the potential that bioethanol provides when replacing traditional sources. The raw material for the production of bio-ethanol is organic wastes from the country's agriculture, which now are currently not used at all, except for the small part that goes to fertilizers. In addition, it is possible to use the resources of landfills, sewage treatment, which will create a powerful for bio-industry in the country. In any farm during the year a significant amount of remains of millet, plants, various wastes are collected. Usually, after decomposition, wastes used as organic fertilizer or animal feed. However, just few people know how much bioethanol is released during fermentation. This source can also serve the villagers well. [7]

Types of plants	Residues on dry weight, million tons
Wheat	11.8
Barley	5.9
Common output	17.7

Table 4: Annual yield of plant residues in Kazakhstan [7]

Kazakhstan was one of the first CIS (Commonwealth of Independent States) countries which try to start a bioethanol plant in 2006. The National Development Bank of Kazakhstan allocated 60 million US dollars for the “Biochem” plant with a capacity of 57000 tons per year. Deep processing of wheat into flour and bioethanol with intermediate stage of extraction of dry gluten, as well as production of fodder yeast and carbon dioxide was provided. However, a fast jump in prices in 3 times for grain had stopped production in the region. Ultimately, production came to bankruptcy, which was caused by rising prices, low demand in the market and a lack of specialists in this field. Small demand in the market was due to the fact that most of the population is simply ignorant of this industry. A relatively high cost of production and an increasing market value of grain limited the spread of bioethanol. If everything goes on in the same way, the production of bioethanol will have no basis in Kazakhstan. However, the Russian group of companies called "Titan" started construction of a plant for the production of bioethanol in the Omsk region. In the short term, legislative changes are expected regarding bioethanol. A full list of legislative acts is adopted to ensure that ethanol is a separate product as a fuel component. At the state level, standards for gasoline with the addition of bioethanol are being developed. [7]

Kazakhstan needs to develop and implement bioenergy development programs to reduce dependence on centralized energy supply, reduce the consumption of traditionally purchased fuels - oil, coal and e-energy by the extensive use of its own energy resources - biomass, plant and wood waste, vegetable oils, the introduction of new energy-efficient technologies, the construction of decentralized autonomous systems with the generation of thermal and electric energy. One of the significant features of Kazakhstan - large-scale production and processing of grain should be taken into account. In the industrial processing and cleaning of grain, a large part goes to waste. In this sphere, an excellent source of raw materials for biofuel production is being formed. I think that this area of biofuel production should be given special attention. [7]

1.2 Production

1.2.1 Wastes

Waste is classified according to several criteria such as appearance, physical state, and the bearing of risk. According to the criteria of appearance, there is production waste (industrial waste) and household waste (municipal). Waste production is waste that occurs after the production process, they are not deliberately; each has its own production of industrial waste. Consumer waste is not applicable to domestic goods and products, as well as unnecessary human products or residues generated in the municipal services system. In aggregate state can be divided into solid, liquid and gaseous wastes. In danger can be divided into the garbage which is dangerous for the people and one that is dangerous for the environment.

Biomass is a collection of plant and animal organisms. Therefore, a large amount of garbage can is classified as biomass because it contains a part of the animal or plant organisms. This type of waste as a municipal solid waste, biological waste, paper, medical, and forestry wastes compelling cost of the biomass. [6]

The one of the well-known type of a biomass is lignocelluloses biomass, so I want to focus on it, which is contained in all the above-mentioned wastes. Lignocelluloses substrates are generally composed of cellulose, hemicelluloses, lignin and a wide variety of organic and inorganic compounds. All biotechnological technologies (anaerobic fermentation, alcoholic fermentation, biogas plants) are based on the treatment of lignocelluloses biomass. [6]

Annual stock of lignocellulose for 2007 is 200 billion metric tons, which is one of the major renewable resources. It includes residues, herbaceous, hardwood, softwood, pulp and waste industrial byproducts. In the table 5 below is shown many kinds of raw materials. [6]

Raw material	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Agricultural residues			
Corn cobs	38.8-44.0	33.0-36.4	13.1-18.0
Corn stover	34.32-36.5	20.11-31.3	11.9-13.55
Wheat straw	33-40	20.0-33.8	15.0-26.8
Rice straw	35.0-36.6	16.1-22.0	12.0-14.9
Sugar cane bagasse	34.1-49.0	15.79-29.6	19.4-27.2
Barley straw	37.5	25.1-37.1	15.8-16.9
Rise husk	33.43	20.99	18.25
Rye straw	41.1-42.1	23.8-24.4	19.5-22.9
Rapeseed straw	36.59-37.0	19.6-24.22	15.55-18
Sunflowers stalks	33.8	20.2-24.27	14.6-19.9
Sweet sorghum bagasse	41.33-45.3	22.01-26.3	15.2-16.47
Herbaceous			
Switchgrass	41.2-32.97	25.95-31.1	17.34-19.1
Alfalfa stems	24.7	14.7	14.9
Coastal Bermuda grass	25.59	19.29	19.33
Hardwood			
Aspen	43.8	18	20.8
Hybrid Poplar	48.95	21.73	23.25
Eucalyptus	44.6	21.4	30.1
Eucalyptus globulus	44.4	21.8	27.7
Softwood			
Pinus radiata	45.3	22.5	26.8
Spruce	43.8	20.8	28.83
Cellulose wastes			
Newspapers	60.3	16.4	12.4
Recycled paper sludge	60.8	14.2	8.4
Industry co-products			
Distiller’s grains	12.63	16.9	-
Brewer’s spent grain	18.8-20.97	15.18-32.8	21.7-25.62

Table 5: Composition of selected lignocellulosic materials (%wt. dry matter). [8]

1.2.2 Overview

Bioethanol is an ordinary ethanol, which is obtained during processing of plant, like a raw material for biofuels. World production of bioethanol in 2005 is 36.3 billion litters, of which 45% was in Brazil and 44.7% in the USA. Raw material for production of bioethanol can be agricultural crops with a high content of starch or sugar: manioc, potato, sugar beet, sweet potato, sorghum, barley and biomass with high quality of cellulose. [9]

As it was written above lignocelluloses biomass is composed of cellulose, hemicelluloses, lignin and a wide variety of organic and inorganic compounds. So I want to focus on of the production from wheat straw, because it is one of the popular bio wastes.

In table below you can see the composition of wheat straw:

Chemical composition (wheat straw)	Cellulose (33-40% w/w), hemicellulose (20-25% w/w), lignin (15-20% w/w)

Table 6: Wheat straw composition [10]

Properties of standard bioethanol described in below table:

Molecular mass	46,069 g/mole
Melting temperature	-114,15 °C
Boiling temperature	78,39 °C
Standard enthalpy of formation	-234,8 kJ/mol (g) (at 298 K)
Standard entropy of formation	281,38 J/molK (g) (at 298 K)
Standard molar heat capacity	1,197 J/molK (g) (at 298 K)
Critical point	241 °C (at 6,3 MPa)
Density ow ethanol	789 kg/m^3

Table 7: Properties of ethanol [11]

In my thesis, the main goal is to create all calculations for the production of 24 000 000 liters per year (not including day for repairs); which is equal to 6 349 206 gallons. The mass flow rate of ethanol from end of process would be around 4166 litters of ethanol per hour or 3271 kg/hour plus containing 5 % of water (1102 gallons per hour). I counted the number of gallons in accordance with the United States gallon, which equals 3.78 liters per gallon. Wheat straw is selected as raw material for production.

1.2.3 Steps of production

Nowadays, production of bioethanol is based on sugar and ethanol from starch, but there are a large number of disputes about sustainability. In this work, I will focus on the utilization of lignocelluloses biomass, as this is a good alternative.

Ethanol production from lignocellulosic biomass comprises the following main steps: pretreatment, hydrolysis of cellulose and hemicellulose, sugar fermentation, separation of lignin residue and, finally, recovery and purifying the ethanol to meet fuel specifications. You can see in figure “1” below step by step processes. The task of hydrolyzing lignocellulose to fermentable monosaccharides is still technically problematic because the digestibility of cellulose is hindered by many physicochemical, structural and compositional factors. Owing to these structural characteristics, pretreatment is an essential step for obtaining potentially fermentable sugars in the hydrolysis step. [12]

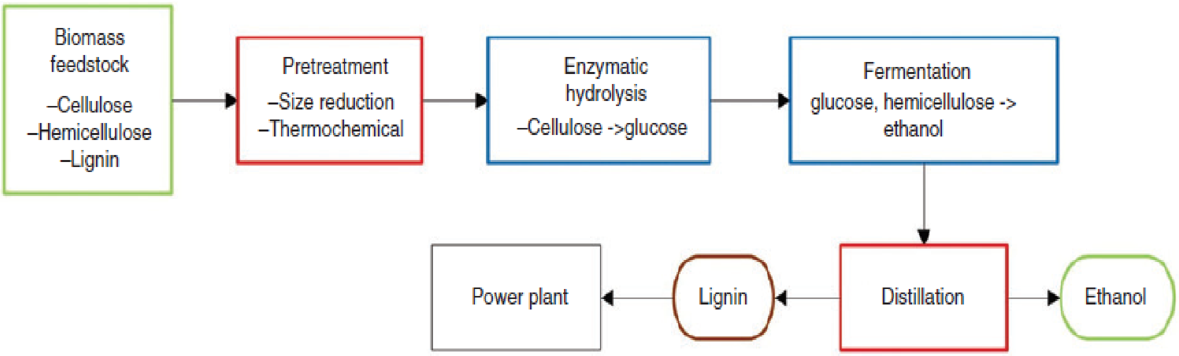


Figure 1: Typical bioethanol production flowsheet [10]

1.2.3.1 Pretreatment

At this time, a large number of pretreatments are used in a wide variety of raw materials. Researches preceding basic treatments focus on the evaluation and development, support for the subsequent enzymatic hydrolysis processing biomass with lower enzyme dosage and shorter bioconversion time. [6]

In accordance with the physical and chemical properties of the individual raw materials, the corresponding pretreatment should be chosen. Certain pretreatment has an effect in further processes of transformation in terms of digestibility of cellulose, and the appearance of toxic compounds. Most pretreatments were administered for in the last decades. They are divided into physical, biological, chemical, physicochemical, in accordance with different force or energy consumed during pretreatment. [6]

1.2.3.1.1 Physical pretreatments

The aim is to reduce the particle size and degree of crystallinity of lignocellulose. In order to decrease the degree of polymerization and to increase the specific surface by combining of milling, grinding or chipping depending on the final particle size of the material (10–30 mm after chipping and 0.2–2 mm after milling or grinding). [6]

1.2.3.1.2 Biological pretreatment

Fungal pretreatment has been investigated to improve the supply of lignocellulosic for feed and paper applications. This method is environmentally friendly and has been received attention as a pretreatment to improve the enzymatic scarification of lignocellulosic biomass to ethanol production process. Biological pretreatment is using microorganisms such as brown, white and soft-rot fungi. One of the commonly used microorganisms is white-rot fungi, as it is the most effective which occurs through the action of lignin-degrading enzymes such as peroxidases and laccases. [6]

1.2.3.1.3 Chemical pretreatment

Acid pretreatment

The main purpose of using acid solubilization is pretreated biomass hemicellulose fraction and makes it more suitable for fermentation. This type of pretreatment may take place with dilute and concentrated acid.

Dilute acid pretreatment are more beneficial to the industry for a wide range of lignocellulosic biomass. Used acids: H2SO4 (often used), hydrochloric acid, phosphoric acid, nitric acid. [6]

Alkali pretreatment

Alkaline pretreatment efficiency depends on the amount of lignin in the biomass. Alkaline pretreatment increases the digestibility of cellulose and improves the efficiency of lignin solubilization. Treatment may take from a few seconds to several days at room temperature. It causes less sugar degradation than acid pretreatment and it was shown to be more effective on agricultural residues than on wood materials. The alkaline pretreatment is performed with using sodium, potassium, calcium and ammonium hydroxides. There is also often used Ca (OH) 2, i.e. lime. [6]

Ozonolysis

Ozone is a strong oxidant. It shows good results in delignification. The parameter of this method is room temperature to normal pressure. In this case, there is no risk of inhibitory compounds, though method is not economically profitable. [6]

Organosolv

Mixtures use a large amount of water or organic solvents, including methanol, ethanol, ethylene glycol, acetone, tetrahydrofurfuryl alcohol. The solvent is removed by extraction and separation, for example, evaporation and condensation, and they must be recycled to reduce maintenance costs. Necessity of removing the solvent is that it can be inhibitory to enzymatic hydrolysis and fermentation of microorganisms. [6]

Lonic liquids (ILs) pretreatment

Due to the complex relationship non-covalent interactions, polymers include cellulose biomass hemicellulose and lignin properly destroyed while minimizing the formation of degradation products. However, the majority of data shows the effectiveness of IL that has been designed using pure crystalline cellulose, and its applicability to more complicated combinations of components in the lignocellulosic biomass needs further investigation. [6]

1.2.3.1.4 Physicochemical pretreatment

Steam explosion: SO_2-steam explosion

Steam explosion pretreatment commonly used method. The biomass is treated with steam under pressure for a few minutes or seconds and then suddenly is depressurized, and it is called hydrothermal pretreatment. This processing is the mechanical bond strength and the chemical effects due to hydrolysis of the acetyl groups in the hemicellulose. Auto hydrolysis is the cause of the acetic acid from the acetyl group under a high temperature; the water may enter also to an acid at a high temperature. The mechanical effect is a consequence of the sharp pressure drop and separation of fiber under explosive decompression. Lignin is removed partially and redistributed through a combination of partial hydrolysis of hemicellulose and solubilization. Cellulose surface exposed by removing hemicellulose, it gives access to cellulose fermentation. [6]

Liquid hot water

The hydrothermal treatment is also present processing liquid hot water. This treatment does not require any catalysts, chemicals, as well as rapid decompression. In order to support liquid water pressure is required, the temperature of 160 °C-240 °C leads to change the structure of lignocellulose. [6]

Ammonia fiber explosion (AFEX)

AFEX pretreatment uses liquid anhydrous ammonia under a high pressure at a temperature of 60 °C and 100 °C for variable time. After the pressure is rapidly reduced, in this regard, the ammonia gas is growing rapidly, due to which the fibers break down biomass, as well as the pulp passes partial decrystallization. [6]

Wet oxidation

Wet oxidation method uses oxygen as a catalyst. Processing occurs with low temperature and short time of the reactor. Working time is 10-15 minutes with the temperature of 170-200 °C and pressure of 1-1.2 MPa. Adding oxygen at a temperature above 170 ° C affect the overall demand for the energy required. The basic reaction in the wet oxidation is the cause of acid from hydrolytic processes and oxidation reactions. [6]

Microwave pretreatment

Process takes 5-20 minutes, by immersion the material in reagents and subjecting the slurry by microwave radiation. The reagent is a caustic sodium hydroxide. [6]

Ultrasound pretreatment

Ultrasound method is poorly understood for the extraction of hemicellulose. However, some tests have shown the effectiveness of this method. [6]

$C0_2$ explosion

In this pretreatment method uses CO_2 as the supercritical fluid. This fluid is in a gaseous state, but is susceptible to pressure at a maximum temperature of the critical point in fluid, as density. This treatment is good destroys lignin improving digestibility of substrate. CO_2 molecules have a similar size as the body of water molecules and ammonia, thereby they can also penetrate into the pores of the cellulignin. This procedure causes a high pressure, which causes an explosion that disrupts the structure of cellulose and hemicellulose, which enhances the ability of the enzyme to attack. [6]

1.2.3.2 Enzymatic Hydrolysis

Hydrolysis process is transforming of cellulose and hemicellulose into sugar by adding of enzymes. In deep view it is mean that carbohydrate is broken by water and enzymes into sugar molecules, which also can be called saccharification. Hydrolysis and saccharification are one process of degradation of a substance. The main types of hydrolysis are broken chemical bonds by dilute acid, strong acid and enzymatic hydrolysis. Using acid in that process is new technology, but hydrolysis by enzymes for nowadays is more prefer because economical cost are less. [13]

Enzymatic hydrolysis is method which is use special organisms that produces enzymes that degrade cellulose into sugar. That method has a big advantage to producing high yield of sugars with few degradation products. In nowadays one of the biggest problems is price for production of enzymes. But today a lot of companies try to solve this problem. [14]

The process of enzymatic hydrolysis is going in such way that a long-chain of carbohydrates present in insoluble structures such as cellulose, hemicellulose and starch are broken down by hydrolases, resulting in short chain sugars. Proteins are broken down into amino acids by proteases. Fats are broken down into fatty acids and glycerin by lipases. The hydrolysis of carbohydrates takes place within a few hours and the hydrolysis of proteins and lipids within a few days. Lignocellulose and lignin are degraded only slowly and incompletely. [6]

In future more efficient enzymes which improved catalytic activity and synergy have to be created, all this can help to reduce price for enzymes which affected in ethanol production. “Strategies to improve enzymes include bioprocessing for superior key enzymes, mining plant pathogens for hydrolytic enzymes, and enzyme engineering of which the latter is of the most importance. It includes mutagenesis, DNA screening, and gene expression or overexpression. Thermostable enzymes have been developed that can function at a temperature range of 60–100°C. Operating at increased temperature would mean higher specific activity of enzymes, which would reduce enzyme loading and higher stability which would allow for longer hydrolysis times.” [10]

1.2.3.3 Fermentation

Fermentation is a metabolic process that takes place in the absence of oxygen and at which sugar is consumed. The end product of this type of process is various acids, gas and alcohol. This process can be observed in yeast, bacteria and also in muscle cells with oxygen, with fermentation of lactic acid. Zymology is a science that studies this process.

After the cellulose and hemicellulose are broken down into sugar, the fermentation process takes place along the center of the yeast. Carbon sugars are easily converted into ethanol. Saccharomyces suspensions are the kind of yeast that is most commonly used in this process. ‘‘For the purpose of fermenting sugars from lignocellulosic where ethanol concentration in the fermentation broth can only reach as high as 10% (w/w), yeast can be considered ethanol tolerant as growth is suppressed at 12% (w/v) ethanol but fermentative capacity is as high as 30% (w/v) ethanol.” [10]

The chemical reaction occurs in such way, one glucose molecule is converted into two ethanol molecules and two carbon dioxide molecules:

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2 \qquad (1.2.3.3\text{-}1)$$

C_2H_5OH is the chemical formula for ethanol.

1.2.3.4 Recovery and purifying

The final process is the separation of ethanol from the fermentation solution, as well as the removing solid particles. In our time there is a large number of technological equipment, which has proven itself well.

Ethanol, obtained by the hydration of ethylene or fermentation, is a water-alcohol mixture containing impurities. Cleaning is necessary for its industrial, food and pharmacopeia applications. By recovery and purifying, the ethanol concentration reaches 95.6% by weight. The resulting liquid is anisotropic with a boiling point of 78.1 ° C. [15]

Most often in the industry, the production of ethanol uses double distillation. The first distillation removes most of the water and dissolved CO_2, and already in the second ethanol is brought to the required concentration.

The second method of purification of ethanol is solid separation. It is very important process in the purification. This process can occur in parallel with distillation or separately. Thus, solid residues from the distillation bottoms are separated and sent to the boiler. Solid residues are most often used to produce energy by burning. The second way of separating the solid matter can occur separately from the distillation. In this case, standard equipment is used as a centrifuge or a mesh. [16]

1.2.4 Evaluation of the review

Agriculture is an important sector of the country's economy. In Kazakhstan, in particular, because of the large number of remote farms from central cities and their dependence on them, cause problems for the local population. However, in these regions there is a great potential in recycling garbage and establishing at least some production, because the population of such remote locations does not have enough jobs. In that type of region there is a lot of biomass, and more specifically straw from millet. Millet is an important agricultural crop that plays a major role in the food industry. However, the residual part such as the straw, leaves and etc. are usually simply burned or left on the field for decay. That immediately tells us about the production of bioethanol.

As mentioned earlier, the process is divided into 4 main steps. For each step there is a variation of its performance. And also for each individual performance there are various special parameters, such as: temperature, concentration of substance, time and level of conversion.

The first stage is mechanical, physicochemical or biological pretreatment, it has a huge number of methods. Since there are many variations, let us take, for example, one of the types of mechanical and physicochemical pretreatment. For mechanical treatment is easiest to choose an apparatus, just take which can disintegrate straw properly. For physicochemical I choose such as liquid hot water pretreatment (in continue and here the LHW will be used as abbreviation). Since this method is well used in the process of processing grain wastes. Of course, the main reason for using this method is the low concentration of hazardous substances.

Further, there are more traditional processes; there are not so many variations in them. Basically parameters for each process can be seen in the table below.

Process	Temp. [°C]	Time	Particle size	Concentration
Mechanical pretreatment	20	Continuous	≤ 30 mm	100% solids
LHW pretreatment	195	3 minutes	≤ 30 mm	5 – 30 % solids (w/v)
Enzymatic hydrolysis	50	24 hours	≤ 30 mm	10 – 30 % solids (w/v)
Fermentation	30	69 hours	≤ 30 mm	10 – 30 % solids (w/v)
Centrifuge	20	Continuous	≤ 30 mm	10 – 30 % solids (w/v)
Distillation	80	Continuous	-	38-40 % ethanol (v/v)
Rectification Purification	70-120	Continuous	-	40-99 % ethanol (v/v)

Table 8: Process parameters of bioethanol production [6]; [17]

2 Practical part

The practical part is a main part of diploma thesis. That chapter was divided into 4 sub characters, such as: process flow diagram, mass balance, energy balance and economic balance. In first sub chapter (process flow diagram, abbreviate PFD) I describe each flow and how it interacts with the subsequent parts of the process. Also the pieces of system of PFD were attached; the separate paper with full diagram is a part of thesis also. The second sub chapter consists of balance of all elements which presence inside of process. Each stream was divided into main components for calculation of percent and mass flow rate. All calculation was created by excel. The last step will be the economic part, where we consider all the costs of implementing the process.

2.1 Process flow diagram

The process flow diagram is an integral part for each production. It show and enumerates all streams and equipment in production, without deep properties. In this thesis, the diagram and table of equipment are attached in a separate documents, appendixes ‘‘A’’ and “C”. This is a preliminary diagram that use to generalize the process of producing bioethanol that why diagram does not indicate such things as several vessels for fermentation, a few columns for distillation, etc. In the total, the diagram contains 41 equipment and 36 streams (without streams for enzymes and yeast). Out of 36 streams, 6 enter production and 5 come out of it.

Process flow diagram is prepared by ‘‘AutoCAD’’. Detailed figures below created by ‘‘Edraw Max’’.

This chapter is divided into 3 parts, such as the main streams, the streams of technical oil and water for heating supply and additional streams. The reason for the fact that streams are divided into separate chapters is in the control of information tripping.

2.1.1 Main streams (“ethanol” streams)

The main streams are the streams where the main processes of the appearance of ethanol take place. These streams are visible on the diagram under numbers from ‘‘0’’ to ‘‘13’’ and from ‘‘15’’ to ‘‘20’’.

2.1.1.1 Pretreatment

2.1.1.1.1 Mechanical pretreatment

Mechanical part (Figure 2) includes ‘‘0’’ and ‘‘1’’ stream. At the beginning of the whole process, the raw material (wheat straw) is loaded into storage vessel under number K-001. This vessel is necessary for storage and dosing of the main component during the day in production. From this storage vessel by conveyor H-001 the raw material enters the disintegrating part. The disintegrating part consists of knife mill (Z-001) and a storage vessel (K-002) attached to it. Then, by a conveyor H-002, the milled portion with size less than 30 millimeter is entered to the pretreatment vessel.

2.1.1.1.2 Hydrothermal pretreatment

This part includes streams ‘‘2’’, ‘‘3’’ and ‘‘4’’, which is possible to see in figure 2. After the raw material has entered the pretreatment vessel number K-003 with inside pressure 1.5 MPa, water for pretreatment added to this vessel by using the pump under number P-010. In the ratio of 10 grams of solid feed in 100 grams of water. The water is stored in a water collector, number T-001, which is supplied by outside water (stream “20”). This procedure takes 3 minutes at a very high temperature of 195 °C. After pretreatment, the mixture is transported into a storage vessel (which is equipped of cooling coils for decreasing temperature for the next procedure) K-004 for the subsequent process. [6]

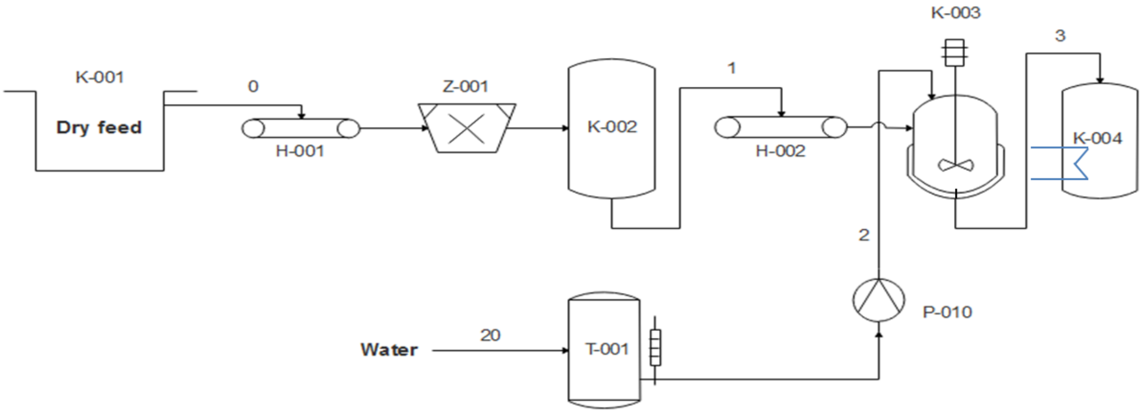


Figure 2: Pretreatment part of PFD of ethanol production

2.1.1.2 Enzymatic Hydrolysis

Hydrolysis streams numbers are ‘‘4-7’’ (Figure 3). Stream number ‘‘4’’ is going from a vessel for storing the pretreated raw material to a vessel for hydrolysis (number K-005). Transportation is carried out by means of a screw pump (P-001). Also to the vessel is supplied by an enzyme in the ratio 10 gram per liter of solution, which is needed for hydrolysis. Residence time of enzymatic hydrolysis is 24 hours under temperature of 50 °C. [18]; [6]

Just like in the pretreatment vessel, the water stream (stream “5”) is connected there from water collector. However, this flow is not necessary for the process and is used to "safe" the process. Additional water can be used for both balance control and for undefined changes in the process. After hydrolysis, suspension under stream ‘‘6’’ is going into a storage vessel K-006 (which is equipped of cooling coils).

2.1.1.3 Fermentation

The process of fermentation is showed under figure below. It is one of the most important processes in the production of ethanol. This process is going in a vessel with the number K-007, in which also is entered some amount of yeast. The vessel is connected to flows ‘‘7-10’’. Streams ‘‘7’’ and ‘‘8’’ enter the vessel, streams ‘‘9’’ and ‘‘10’’ exit from it. Stream number ‘‘7’’ is a continuation from the previous vessel on hydrolysis. Just like in the hydrolysis vessel, an additional flow of water passes through the vessel for fermentation and is of a similar nature as in the above-mentioned process. As this reaction vessel receives a reaction to produce ethanol, it contains gases that leave the process by means of fans P-015, which suck the gases out of the vessel. Next, the whole mixture passes into the next storage vessel (K-008, which is equipped of cooling coils) by screw pump P-003.

Since the process of fermentation takes place for three days under the temperature of 30 °C. It should be mentioned that three or more vessels will be used in the real process. This is necessary for the continuous production of ethanol. The transition of the mixture between the vessels for fermentation will occur daily from one to the other, thus ensuring continuity.

The CO_2 produced by the fermentation leave the production. Further it can be used in syngas production. This is used in the electrical and thermal industries, as well as in the production of carbon monoxide, hydrogen and the synthesis of methanol.

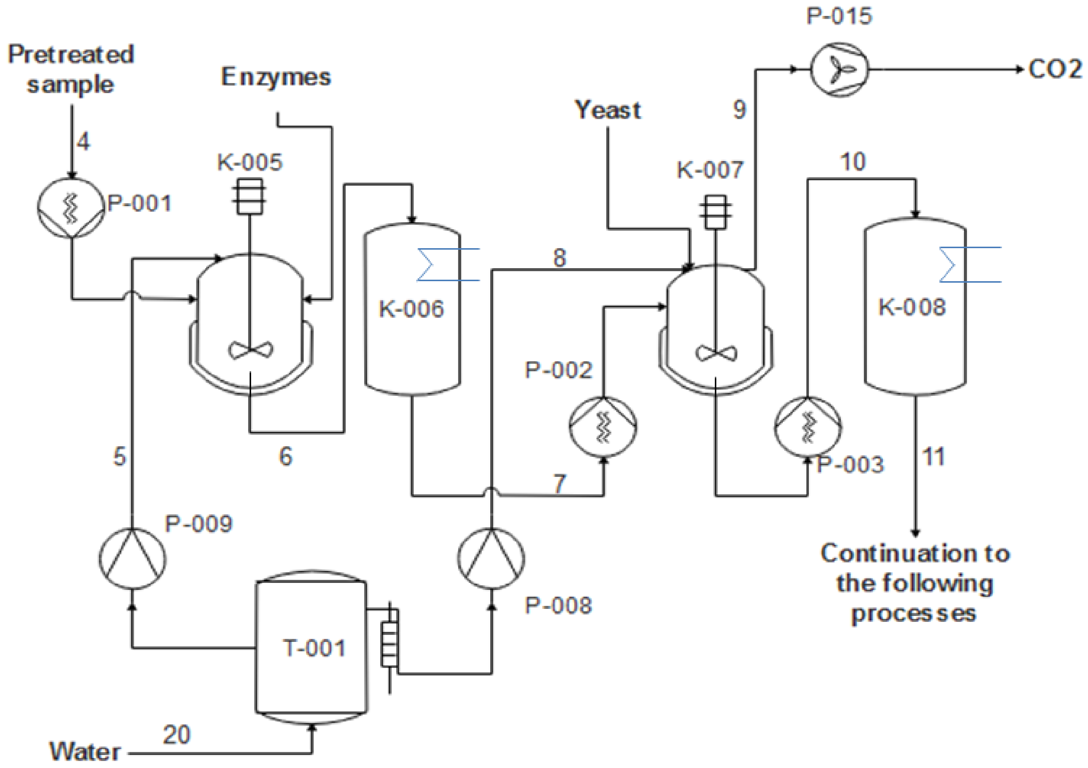


Figure 3: Enzymatic hydrolysis and fermentation parts of PFD of ethanol production

2.1.1.4 Recovery & Purifying

2.1.1.4.1 Centrifuge

The final step for production is the purification of ethanol. This step involves the separation of the solid and liquid parts. Stream ‘‘11’’ enters a centrifuge (F-001) that separates the solid residue. The solid residue (stream “12”) leaves in a vessel K-010 for storing solid waste, but it absorbed some amount of water. Then they will be recycled. The flow of liquid leaves the centrifuge without any solid particles (stream “13”) and passes into a storage vessel K-009 for subsequent purification.

2.1.1.4.2 Distillation

The next step is increasing the concentration of ethanol by removing excess water. Stream ‘‘15’’ is pumped to the distillation Colum by pump P-005. In this column ethanol is separated from a large amount of water by temperature of 80 °C into a gaseous form. The concentration of ethanol reaches 40% v/v but still has a large amount of water. The water that was separated leaves the distillation column in stream ‘‘19’’. The water that has been separated goes into the storage vessel (T-001) and is applied further in the process. Ethanol vapor leaves the column with a stream ‘‘16’’**.**

The gaseous form of ethanol must be transferred back to the liquid form. For this, we use heat exchanger under number W-001. After this, ethanol is stored in a storage vessel (K-012). In this vessel, the remaining gaseous form goes back to the distillation column. The liquid form continues to rectification and purification under stream ‘‘17’’. After rectification and purification the concentration of ethanol in stream ‘‘17.1’’ reaches 95% -99% v/v, the remaining water is returned to the distillation column by stream ‘‘18.1’’.

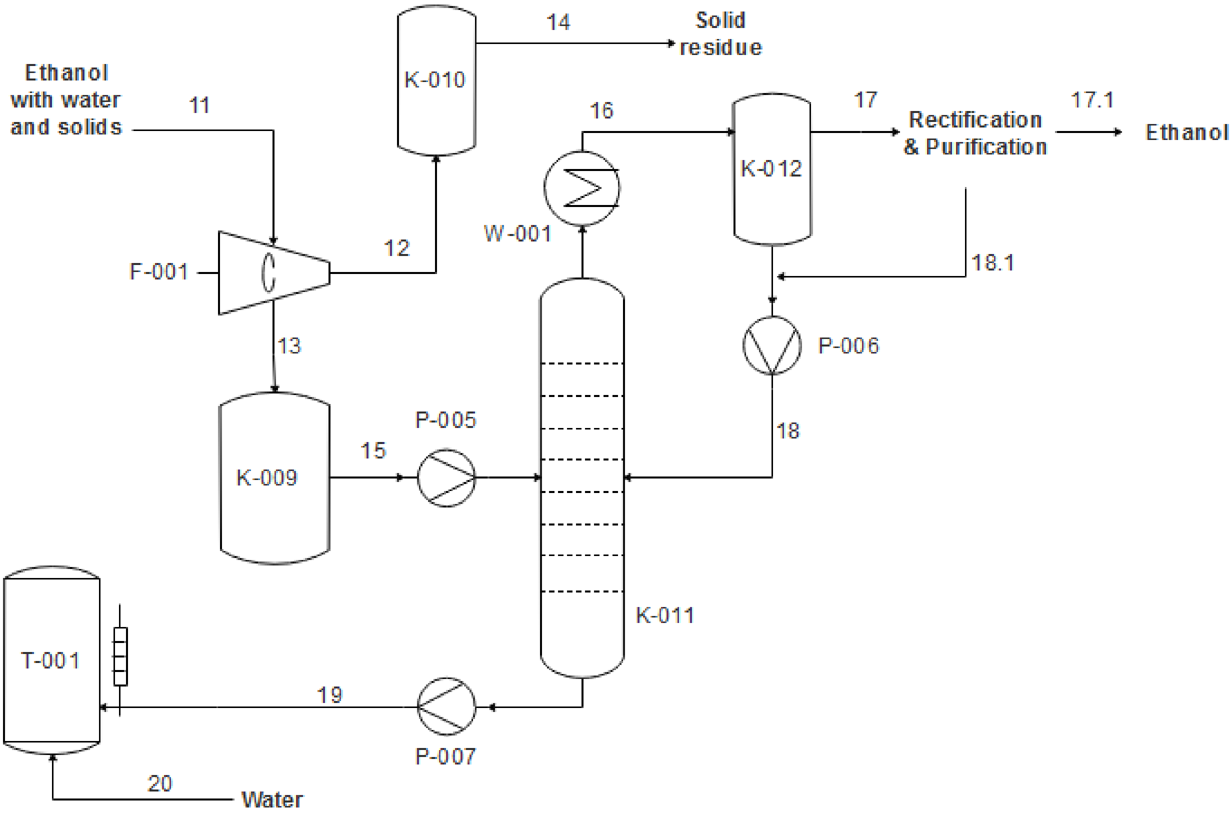


Figure 4: Recovery and purification part of PFD of ethanol production

2.1.2 Technical oil and water streams

Technical oil and water streams (Figure 5 and 6) are flows that do not participate in the process of producing ethanol and are used as energy resources for thermodynamic processes. For example, they are used in double jackets for heating or cooling and do not have a direct contact with the mixture of ethanol.

These streams were divided into two different heating loops. The first heating loop uses water as a heat conductor, and the second loop uses heating oil as a conductor. The reason they were divided is the big difference in temperature. Thus, for pretreatment the high temperature is required (195 °C), it is more convenient to use the heating oil since it can be stay in the liquid state at such temperatures. In the process of hydrolysis and fermentation, the operating temperature does not exceed 50 °C, and it will suffice to use ordinary water.

Technical heating oil enters at stream ‘‘36’’ with a temperature 20 °C and store in the oil distribution tank T-004. This tank preheats the oil to the desired temperature 215 °C by electrical heating coil. Then the oil is pumped by pump P-014 to the double jacket of vessels for pretreatment. In figure below is possible to see the loop:

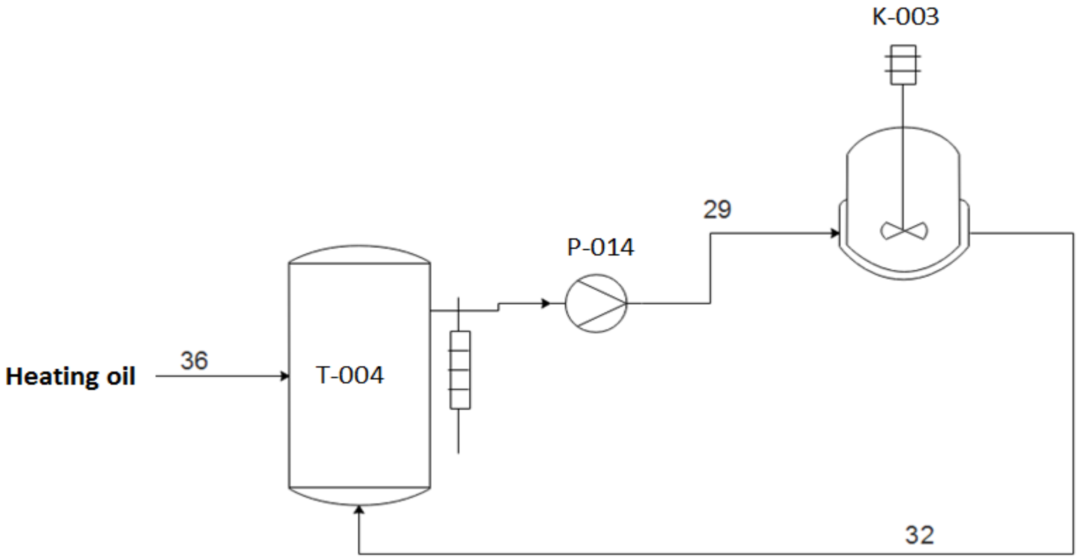


Figure 5: Technical heating oil loop part of PFD of ethanol production

After use, the oil leaves the double jackets into the same tank and is reused.

Technical water loop consist of two vessels and two tanks. The water enters at stream ‘‘28’’ with a temperature 20 °C and store in the water distribution tank T-003. This tank preheats the water to the desired temperature 53 °C by electrical heating coil. Then the water is pumped into two vessel by pumps P-012 and P-013 to the double jacket of vessels for hydrolysis and fermentation. In figure below is possible to see the loop:

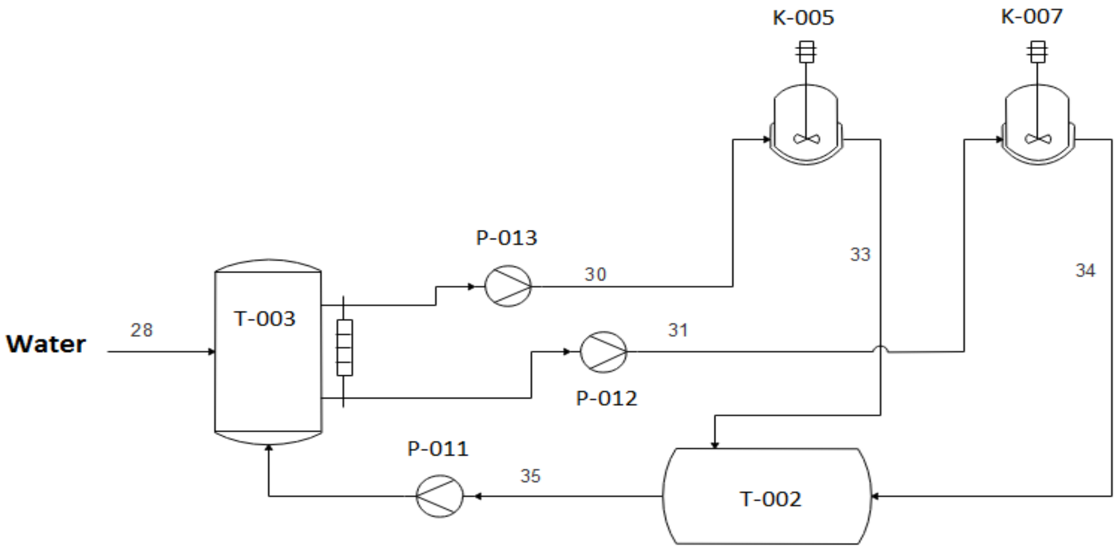


Figure 6: Technical water loop part of PFD of ethanol production

After use, the water leaves the double jackets into the water collector T-002 and is reused due to the connecting stream (stream “35”) with pump P-011 between two tanks.

2.1.3 Additional streams

In the additional flows, I included the use of a solid residue (Figure 7). The solid residue is stored in a storage vessel K-010. From vessel solid residue enters the dryer D-001 by a screw pump P-004. After the drier the residue passes into the combustion chamber B-001. Air for drying enters the dryer with stream ‘‘21’’ with a temperature 100 °C, which is preheated by heat exchanger W-002. Air after use is sucked from dryer by ventilator P-016 with a flow ‘‘22’’ and it has a temperature 65 °C.

The combustion oven B-001 destroys the last remnants of the solid material. Then burned residue is left is the process by stream ‘‘27’’. The oxygen which is need for combustion enter to the equipment through stream ‘‘24’’. The heat released during burning is used in the process for heating the air (Heat Exchanger W-002) for drying and then leave the process trough stream ‘‘26’’.

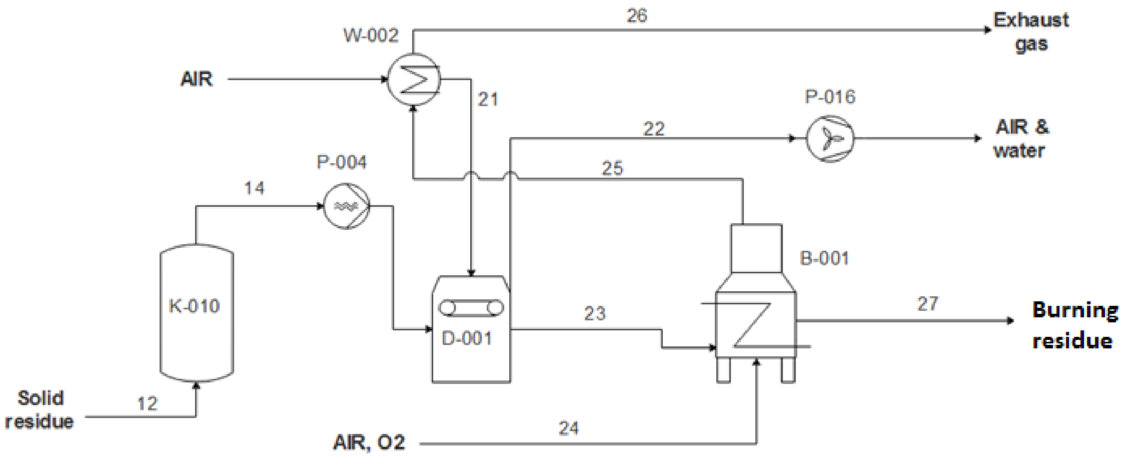


Figure 7: Additional part of PFD of ethanol production

2.2 Mass balance

Mass balance or material balance is principle which is widely used in engineering and analytics and in other fields of activity. The principle is based on preserving the mass for various systems. It is means that the material cannot spontaneously disappear or appear in the system just itself. The main rule is that the incoming stream or streams must equal the output stream.

The mass balance in this thesis is divided into 2 parts. The first part is analysis of the streams for ethanol production and streams for utilization the solid residue. In the second part was created the analysis of streams for supply the heat into equipment. Also in the second part the energy balance will be included, because the heating coils are associated with the transfer of heat. As was outlined above, the process contains 36 streams and 41 equipment, which were analyzed in this chapter. However, not all equipment were taken into account, since mass balance means the number of elements in the process and their movement, and some streams contain several equipment that do not important for these factors.

All calculations were made in the Excel file (appendix ‘‘B’’). The file is divided into four pages, taking into account the division of chapters in the thesis. On the first page there is a file with the analysis of the main streams for the production of ethanol, as well as the utilization of the solid residue. The first page contains a small process flow diagram with the numbering of all the equipment and streams, as well as tables which are named by the number of streams or equipment. Each table contains information about composition in a given stream or equipment, as well as the mass flow per hour and the percentage of the total amount of the substance.

The second page of appendix ‘‘B’’, contains an analysis of the system for heating. On this page there is also a process diagram of streams with numbering, as well as tables containing basic information.

2.2.1 Mass balance of ethanol streams & utilization streams

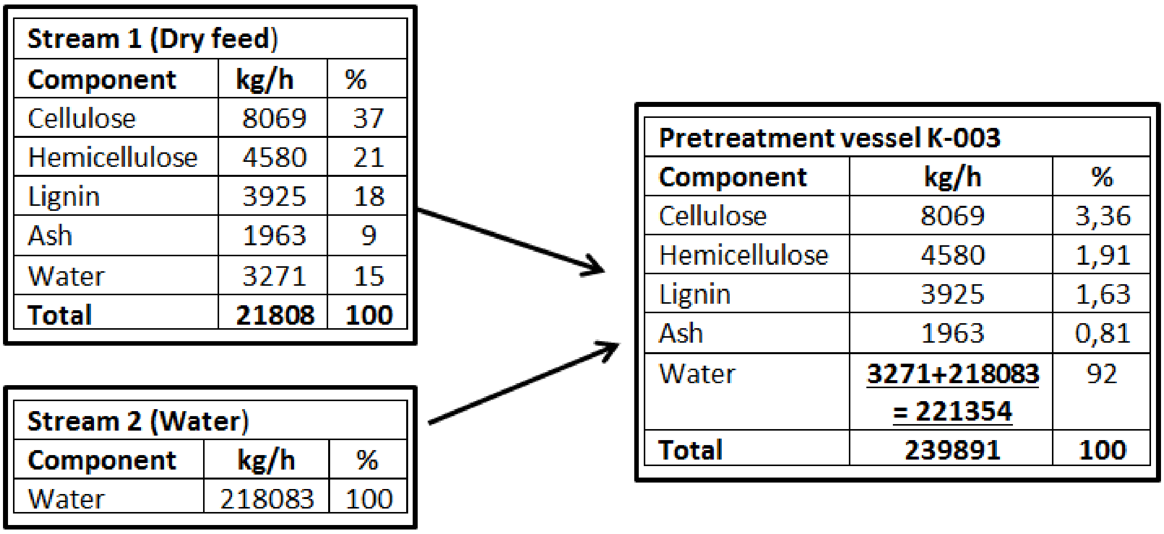
The mass balance begins with the fact that it is necessary to determine the amount of ethanol production and with this information is possible to determine the amount of solid feed. In this thesis, 100 thousand liters of ethanol per day were chosen, which is quite a low amount compared with big facilities. For calculation of mass balance we used unit kg/h. This means that 100 000 liters of ethanol should be converted into kilograms. According the physical property of ethanol, density is 785.1 kg/m^3. We can easily calculate that 78510 kilograms of ethanol will be produced per day. It is also necessary to divide this number to 24 hours in a day for a mass calculation per hour. In the end, 3271 kilograms of ethanol per hour is a goal of production.

The raw material is wheat straw as mentioned in the chapters above. Based on a variety of scientific source (sources will be in the Reference list), the amount of ethanol produced from wheat straw is highly variable and depending on a large number of factors, but it is approximately from 10 to 20 grams from 100 grams of straw. After consultation with the supervisor, we came to the conclusion that in this work will be selected 15 grams of ethanol from 100 grams of straw. Since that 15% of the wheat straw converts into ethanol, for obtaining 78510 kilograms (100 000 liters) of ethanol is required 523 400 kilograms of feed per day. From this it follows that for the mass balance we need 21808.3 kg of feed per hour.

2.2.1.1 Streams ‘‘1-4’’

Stream one is a stream of dry raw materials that has passed all the necessary mechanical pretreatment processes. It has already been stated above that we need 21808.3 kg per hour of dry wheat straw. The straw was divided into the main components: cellulose, hemicellulose, lignin, ash and moisture. Below in the figure “7” the amount of components in the straw is indicated.

The dry feed mixed with water in a first pretreatment vessel in a ratio of 1/10, which means that the solid loading is about 10% w/w. From this data we can get the amount of water necessary for the process. Water comes in an amount of 218 083 kg/ hour by stream ‘‘2’’. The result is shown in figure below. [6]



Stream 1 (Dry feed)		
Component	**kg/h**	**%**
Cellulose	8069	37
Hemicellulose	4580	21
Lignin	3925	18
Ash	1963	9
Water	3271	15
Total	**21808**	**100**

Stream 2 (Water)		
Component	**kg/h**	**%**
Water	218083	100

Pretreatment vessel K-003		
Component	**kg/h**	**%**
Cellulose	8069	3,36
Hemicellulose	4580	1,91
Lignin	3925	1,63
Ash	1963	0,81
Water	**3271+218083 = 221354**	92
Total	**239891**	**100**

Figure 8: Mass flow rate and % of components in the pretreatment

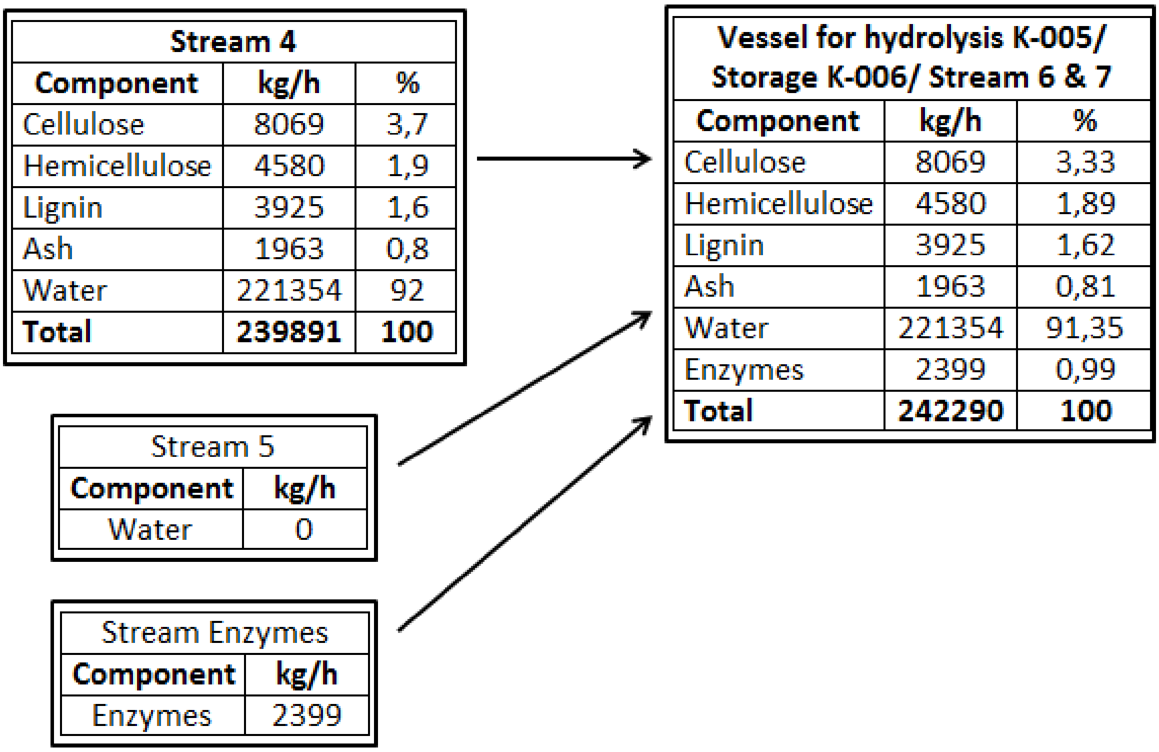
After pretreatment, the sample is sent to the next vessel for hydrolysis. The concentration of components does not change at the time of movement between pretreatment and hydrolysis.

2.2.1.2 Streams “5-7”

In the equipment for enzymatic hydrolysis, cellulose and hemicellulose are transformed into sugar chains by enzymes. The number and type of enzymes greatly depend on the production. It is also known that the concentration of enzymes is very small in sample. Together with the supervisor according different sources we came to the conclusion that 10 grams per liter of the sample would be enough. [18]

When enzymes enter the vessel K-005, concentrations of components inside will change. In figure below you can see dates about concentration into the vessel and in stream “6” which is going out from vessel. Further, the concentrations remain the same until the next process.

Also the vessel is connected to stream “5”, which is used as an additional one. It does not play any role in process, so the mass flow inside is 0 kg/h, but this stream can be used in several cases. For example, the stop or breakdown of the first vessel for pretreatment, in that case the vessel for hydrolysis assume role of vessel for pretreatment. Also, the additional stream can be used in case of a change in the type of pretreatment, and then water will be needed in the hydrolysis stage. Often safe stream water is required to control the pH in the system, etc.



Stream 4		
Component	**kg/h**	**%**
Cellulose	8069	3,7
Hemicellulose	4580	1,9
Lignin	3925	1,6
Ash	1963	0,8
Water	221354	92
Total	**239891**	**100**

Stream 5	
Component	**kg/h**
Water	0

Stream Enzymes	
Component	**kg/h**
Enzymes	2399

Vessel for hydrolysis K-005/ Storage K-006/ Stream 6 & 7		
Component	**kg/h**	**%**
Cellulose	8069	3,33
Hemicellulose	4580	1,89
Lignin	3925	1,62
Ash	1963	0,81
Water	221354	91,35
Enzymes	2399	0,99
Total	**242290**	**100**

Figure 9: Mass flow rate and % of components in the enzymatic hydrolysis

2.2.1.3 Streams “8-11”

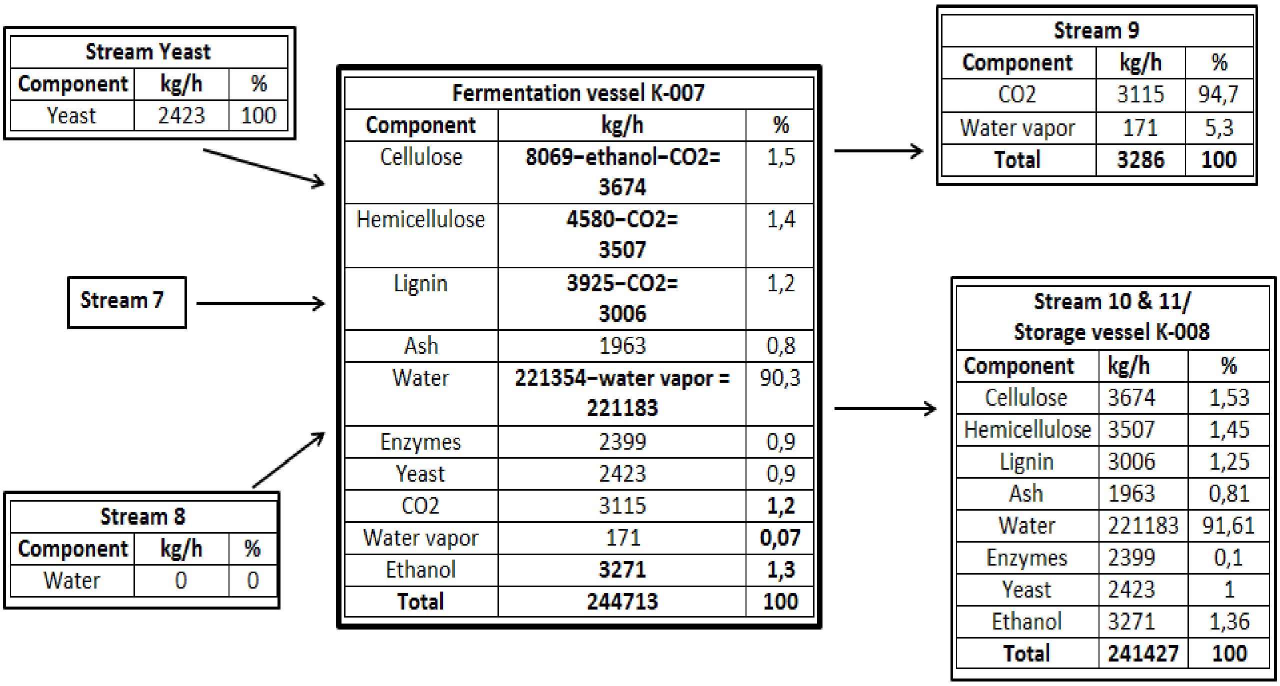
The process of fermentation is an integral process in the production of bioethanol. In this process, sugar is transformed into ethanol under the influence of yeast. As with the hydrolysis process, the amount of yeast is variated from process to process, but everything is also very small. On the advice of the supervisor, the amount of yeast was chosen at 10 grams per liter of the sample. [18]

The concentration of components in the vessel for fermentation will change in view of the entering of yeast, the transformation of the cellulose to ethanol and the release of carbon dioxide gas. As already mentioned above, our goal is 3271 kg of ethanol per hour, and also the fact that ethanol is obtained through the transformation of sugars derived from cellulose, which occupies 37 % w/w in straw (8069 kg/h). In this case, taking the amount of ethanol from the cellulose, it can be shown that about 40 % of the cellulose has passed into ethanol. [10]

The CO_2 gas released during the reaction leaves the production by stream "9". The weight ratio of ethanol/CO_2 is 1.05. Hence it can be said that 3271 kilograms of ethanol produced 3115 kg of carbon dioxide. At the same time, according to the information received from the teacher, the amount of water vapor that also leaves the production together with the gas is approximately 5.5% of gas weight. Therefore the sample lost 171 kg of water. [17]

Also, a stream of additional water "8" is used for the fermentation, which is used in the same manner as in the hydrolysis process.

After fermentation, the gas and liquid are separated. The liquid sample continues its way further (streams "10" and "11", storage vessel K-008). Since the gas mixture has separated the concentration in liquid phase changed. The figure below shows the percentages of components of these streams and how they changed.



Stream Yeast		
Component	**kg/h**	**%**
Yeast	2423	100

Stream 7

Stream 8		
Component	**kg/h**	**%**
Water	0	0

Fermentation vessel K-007		
Component	**kg/h**	**%**
Cellulose	**8069-ethanol-CO2= 3674**	1,5
Hemicellulose	**4580-CO2= 3507**	1,4
Lignin	**3925-CO2= 3006**	1,2
Ash	1963	0,8
Water	**221354-water vapor = 221183**	90,3
Enzymes	2399	0,9
Yeast	2423	0,9
CO2	3115	**1,2**
Water vapor	171	**0,07**
Ethanol	**3271**	**1,3**
Total	**244713**	**100**

Stream 9		
Component	**kg/h**	**%**
CO2	3115	94,7
Water vapor	171	5,3
Total	**3286**	**100**

Stream 10 & 11/ Storage vessel K-008		
Component	**kg/h**	**%**
Cellulose	3674	1,53
Hemicellulose	3507	1,45
Lignin	3006	1,25
Ash	1963	0,81
Water	221183	91,61
Enzymes	2399	0,1
Yeast	2423	1
Ethanol	3271	1,36
Total	**241427**	**100**

Figure 10: Mass flow rate and % of components in the fermentation vessel

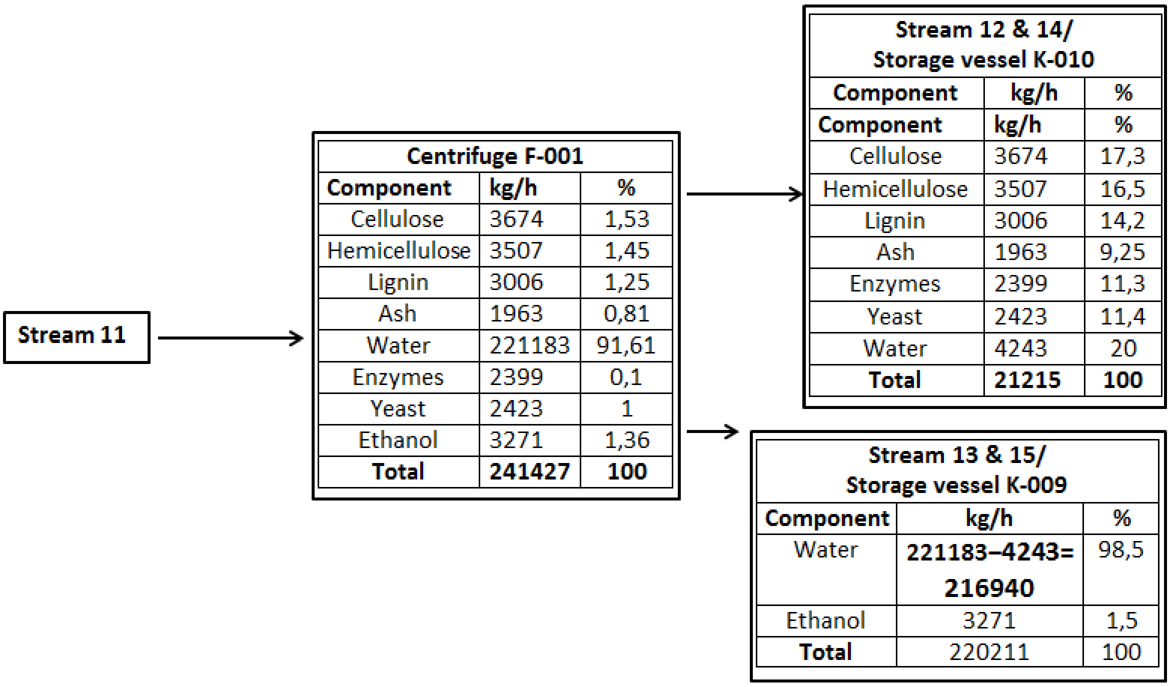
2.2.1.4 Streams “12-15”

After fermentation the liquid and solid phases are passing through the centrifuge for 241 427 kg/h. The stream “12” leaving the centrifuge contains only a solid residue, and the stream “13” leaving the centrifuge only with liquid. In thesis, it was decided that the solid residue would be completely separate from the liquid. Therefore, the percentage ratio in the streams will change.

Stream “12” contains components such as: cellulose, hemicellulose and lignin. Enzymes and yeast also leave the liquid phase together with the solid residue. The residues contain water that has been absorbed during previous processes. The amount of water soaked in the remains of straw is 20% w/w. This amount of water was taken approximately after consultation with supervisor. Then stream enters the storage vessel K-010 from which the solid residue goes to the processing stage. At the same time, the concentration and flowrate in the vessel /stream does not change.

After division, the liquid part contains 216 940 kilograms of water per hour which lost a 4243 kg by solid residue absorption. Further, in stream “15” and in a storage vessel, the mass flow of water and ethanol does not change.

Figure “10” shows how the centrifuge divides the solid and liquid phases. This change the mass flow rate and concentration in the streams.



Centrifuge F-001

Component	kg/h	%
Cellulose	3674	1,53
Hemicellulose	3507	1,45
Lignin	3006	1,25
Ash	1963	0,81
Water	221183	91,61
Enzymes	2399	0,1
Yeast	2423	1
Ethanol	3271	1,36
Total	**241427**	**100**

Stream 12 & 14/ Storage vessel K-010

Component	kg/h	%
Component	**kg/h**	**%**
Cellulose	3674	17,3
Hemicellulose	3507	16,5
Lignin	3006	14,2
Ash	1963	9,25
Enzymes	2399	11,3
Yeast	2423	11,4
Water	4243	20
Total	**21215**	**100**

Stream 13 & 15/ Storage vessel K-009

Component	kg/h	%
Water	**221183–4243= 216940**	98,5
Ethanol	3271	1,5
Total	220211	100

Figure 11: Mass flow rate and % of components in centrifuge

2.2.1.5 Streams “16-20”

One of the most recent steps in obtaining ethanol is distillation. Water and ethanol enter the column K-011 with the mass flow rate 220 211 kilograms per hour (Figure 11). In a column, under the influence of temperature, ethanol vapor is separated from liquid water, but ethanol vapor still contains about 60% w/w of water vapor. Ethanol and water vapor leave the column through stream “16” at a mass flow rate of 8411 kg/h. This number is the sum between the amount of ethanol (target 3271 kg per hour) and water vapor which has separated from water in an amount of 60% by weight of ethanol. [17]

Then vapors are condensed and transferred to a vessel K-012 where the remains water vapor going back into the column through stream “18”, thereby increasing the concentration of ethanol. After the whole process of distillation, the percentage of ethanol reaches 40% v/v. [17]

The final stage separates all remains, thereby increasing the concentration of ethanol to 95% v/v. In a real process, the concentration of ethanol cannot reach 100% v/v; it is around from 95% to 99% v/v. For this work, we take a smaller result for a more accurate calculation. 5% v/v of the remains water tells us that 172 kg/h of water should be taken away from the input stream with an amount of water of 4907 kg/h, the resulting number will give us the amount of water that is returned to the column. [17]

Most of the water in the distillation column K-011 is in the amount of 211 800 kilograms per hour. This number is the difference between the water that entered the column and the water that passed into the gaseous state with ethanol. This water goes to the tank T-001 for storage and re-use. This tank contains the water necessary for the process.

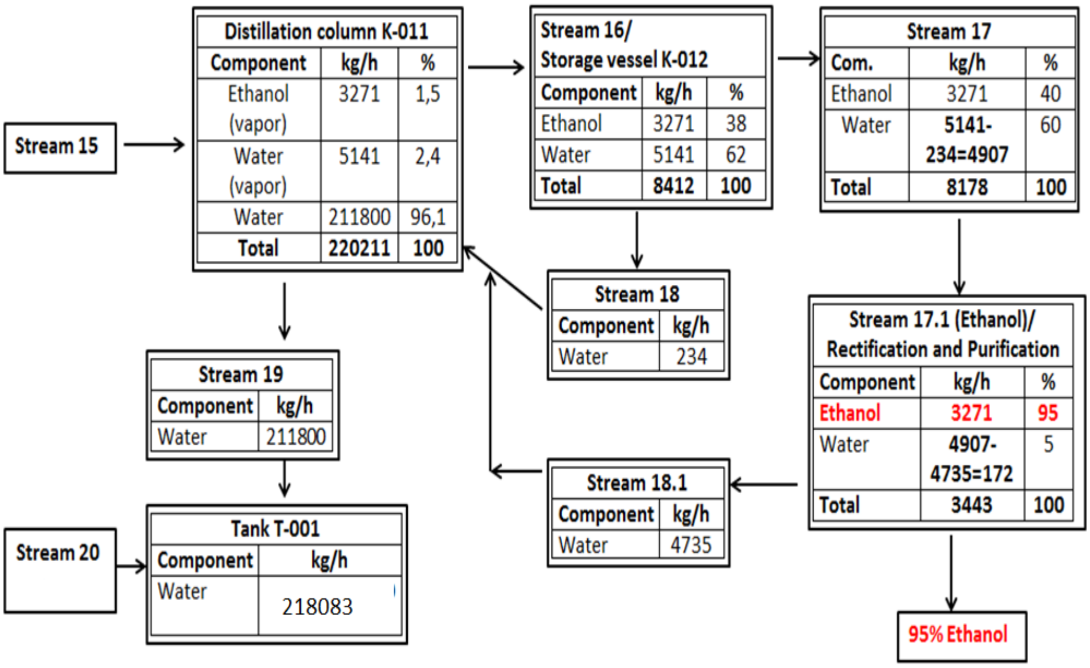
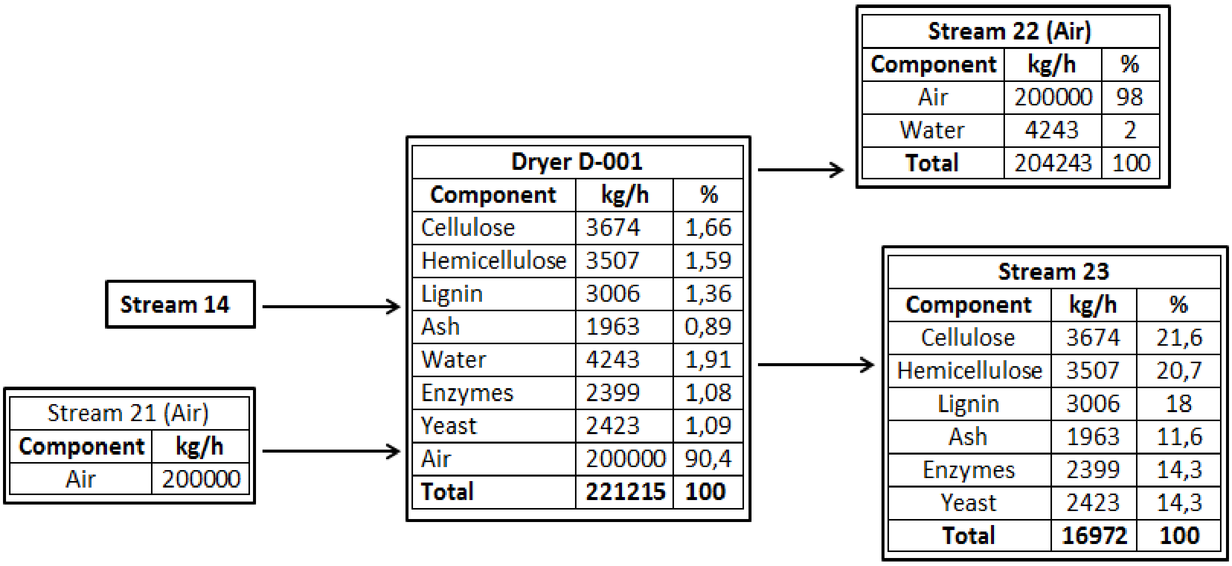


Figure 12: Mass flow rate and % of components in the distillation etc.

2.2.1.6 Stream “21-23”

The solid residue enters the dryer in which air is supplied with the mass flow rate of 200 000 kilogram per hour. This number was calculated by a calculator that will be attached as an appendix "X". Concentration in the dryer taking into account the incoming air, see in figure “12”. The drying process was presented as ideal, in which 100% of the water goes out from solid material. That is, after the centrifuge as mentioned above, the material absorbed 4243 kg of water and hence all this water left the dryer together with air (stream “22”). Further, the whole solid residue traveled through stream “23” to the combustion chamber, where the total concentration and mass flow rate changed taking into account the water removing.



Stream 14

Stream 21 (Air)	
Component	**kg/h**
Air	200000

Dryer D-001		
Component	**kg/h**	**%**
Cellulose	3674	1,66
Hemicellulose	3507	1,59
Lignin	3006	1,36
Ash	1963	0,89
Water	4243	1,91
Enzymes	2399	1,08
Yeast	2423	1,09
Air	200000	90,4
Total	**221215**	**100**

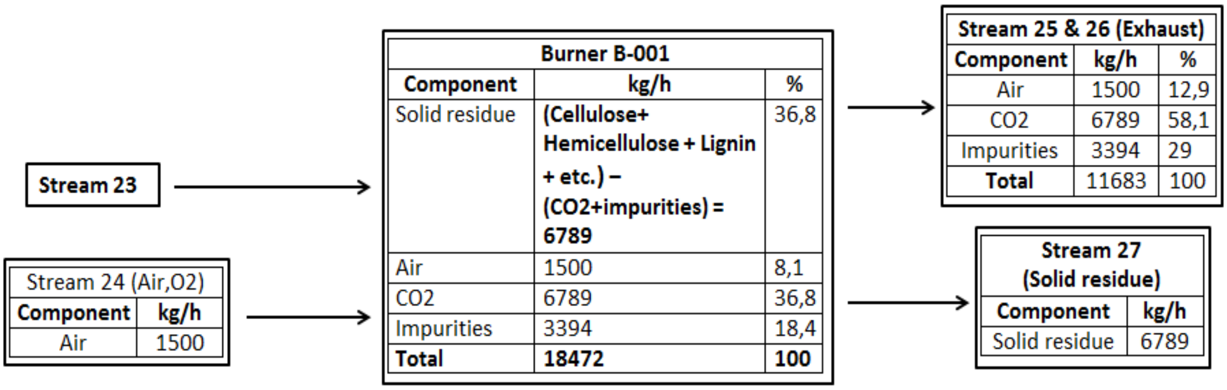
Stream 22 (Air)		
Component	**kg/h**	**%**
Air	200000	98
Water	4243	2
Total	204243	100

Stream 23		
Component	**kg/h**	**%**
Cellulose	3674	21,6
Hemicellulose	3507	20,7
Lignin	3006	18
Ash	1963	11,6
Enzymes	2399	14,3
Yeast	2423	14,3
Total	**16972**	**100**

Figure 13: Mass flow rate and % of components in the dryer

2.2.1.7 Stream "24-27"

The combustion chamber burns solid residues in the amount of 16972 kilograms per hour. The solid residue is the sum of the remaining cellulose, hemicellulose, lignin, enzymes, yeast and ash. For the combustion was needed 1500 kilograms of air per hour. In this case, carbon dioxide is released. Straw contains approximately 40% w/w of carbon, while burning 99% of carbon is converted to CO_2. Also, the straw contains other volatile elements that also go along with the gas. Solids residues are left after combustion is the ash which leaves production. [19]



Stream 23

Stream 24 (Air,O2)	
Component	**kg/h**
Air	1500

Burner B-001		
Component	**kg/h**	**%**
Solid residue	**(Cellulose+ Hemicelluose + Lignin + etc.) – (CO2+impurities) = 6789**	36,8
Air	1500	8,1
CO2	6789	36,8
Impurities	3394	18,4
Total	**18472**	**100**

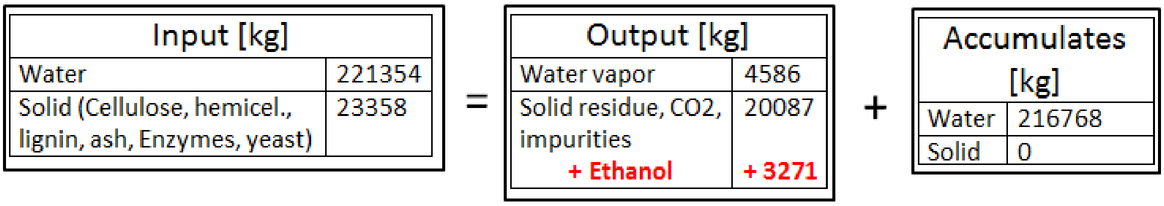
Stream 25 & 26 (Exhaust)		
Component	**kg/h**	**%**
Air	1500	12,9
CO2	6789	58,1
Impurities	3394	29
Total	11683	100

Stream 27 (Solid residue)	
Component	**kg/h**
Solid residue	6789

Figure 14: Mass flow rate and % of components in the burner

2.2.1.8 Results

As a result, we can say with confidence that the main principle of mass balance is preserved in this analysis. The substance of the system is uncreatable and indestructible. In this analysis, all incoming components are equal to the output or accumulated in the system. According to the law "The input is equal to the output plus the accumulation". The figure below shows that 23 358 kilograms of solid raw components were loaded in the process, and 20 087 came out in the form of ash and gases, everything else turned into the required amount of ethanol (3271 kilograms). The same was done with water, all the water entering the process including water contained in solid raw materials came out of the production in the form of water vapor in the amount of 4586 kilograms, all the remaining water was preserved in the process.



Input [kg]	
Water	221354
Solid (Cellulose, hemicel., lignin, ash, Enzymes, yeast)	23358

=

Output [kg]	
Water vapor	4586
Solid residue, CO2, impurities + Ethanol	20087 + 3271

+

Accumulates [kg]	
Water	216768
Solid	0

Figure 15: The result of mass balance

2.2.2 Mass and energy balance of heating technical streams

The analysis of mass balance for heating streams is shorter, but more complicated. For heating we use oil and water. Since this stream is used for heating and does not with touch with the components inside the reactors and only flows through the heating jackets the percentage does not play any role in balance. We only use process parameters such as temperatures, residence time and volume to measure the mass flow of oil or water. Since the oil/water is flowing through the reactors and transfer heat to the processes which occur inside, the temperature of the given oil/water will be higher at the inlet of the jacket. All these data will affect to the mass flow rate of oil/water.

This chapter includes the energy balance of equipment, since we will determine the mass flow rate by the transfer of heat to the equipment.

2.2.2.1 Pretreatment Vessel K-003

With the help of the law about heat transfer which is widely used in engineering, it is possible to calculate the mass flowrate inside of oil loop. It consists of mass flowrate, specific heat capacity and temperature difference before and after heat exchange. This tells us that controlling the mass flowrate can also control the temperature transferred to the vessel. The fundamental equation:

$$Q = m' * Cp * dT \qquad (2.2.2.1\text{-}1)$$

Where:

- Q……..heat transfer rate [kW]
- m’.........mass flow rate [kg/s]
- Cp……specific heat capacity [kJ/kg*K]
- dT……temperature difference [K]

Also, we can express heat through the specific heat loss in [W/m3] and the volume of the vessel in [m3], the formula is presented below.

$$Q = E * V \qquad (2.2.2.1\text{-}2)$$

If we equate the right-hand sides of these two formulas, we get:

$$E * V = m' * Cp * dT \qquad (2.2.2.1\text{-}3)$$

Further, we can express the mass flow and get:

$$m' = \frac{E * V}{Cp * dT} \qquad (2.2.2.1\text{-}4)$$

It remains to substitute the numbers. Specific heat loss I received from my supervisor it will be equal to 35 W/m3. Specific heat capacity of heating oil will be 2000 J/kgK (specific heat capacity varies according the temperature and pressure, but on the advice of the supervisor in this case was simplified). The temperature differences were taken approximately. If for the process, the required temperature inside the vessel is 195 °C, then the input and output temperature in double jacket will be slightly larger. In this way, the temperature at input 215 °C and at output 200 °C were selected. The volume of the vessel was chosen according to the volume and residence time of the sample inside. If the necessary mass flow rate in this vessel is 240 000 kg per hour and residence time 1 hour (in the course of an hour the sample heats from 20 °C to 195 °C degrees, the last 3 minutes is a pretreatment), then the volume of the vessel will be 12 cubic meters (according equation 2.2.2.1-5). [20]

$$V = V' * t = \frac{m'}{\rho} * t = \frac{240000}{1000} * 1 = 240\ [m^3] \qquad (2.2.2.1\text{-}5)$$

Where:

- V……..volume of equipment [m^3]
- V'…….volume flow rate [m^3/h]
- t………residence time [hour]
- m'…….mass flow rate [kg/h]
- ρ……..density [kg/m^3]

It follows that the volume is 240 m^3, but should be taken with a stock. Further the mass flow rate of oil inside of jacket:

$$m' = \frac{35 * 240}{2000 * 15} = 0{,}28 \quad [\frac{kg}{s}] \qquad (2.2.2.1\text{-}6)$$

Since in this thesis we use kilograms per hour, we transfer the answer:

$$m' = 0{,}28\ \left[\frac{kg}{s}\right] * 3600 = 1008\ [\frac{kg}{h}] \qquad (2.2.2.1\text{-}7)$$

Below is a figure with explanations:

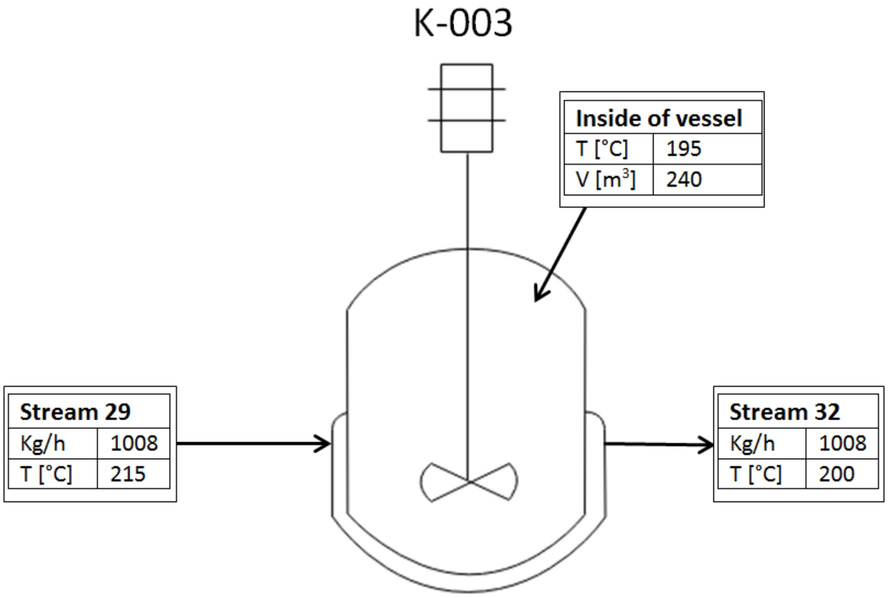


Figure 16: Mass balance of oil heating loop in pretreatment vessel

2.2.2.2 Enzymatic Hydrolysis vessel K-005

In the vessel for hydrolysis, the ways of calculation remain the same. The temperature of the vessel inside 50 °C, the entering temperature in the jacket 70 °C, and at the outlet 55 °C. Specific heat capacity of water will be 4180 J/kgK (specific heat capacity varies according the temperature and pressure, but on the advice of the supervisor in this case was simplified). Volume of vessel are changed according the residence time and flow rate, process are going 24 hours. [6]

Volume of vessel:

$$V = \frac{243000}{1000} * 24 = 5832\ [m^3] \approx 6000\ [m^3] \qquad (2.2.2.2\text{-}1)$$

Further mass flow is calculated:

$$m' = \left(\frac{35*6000}{4180*15}\right) * 3600 = \ 12057\ \left[\frac{kg}{h}\right] \qquad (2.2.2.2\text{-}2)$$

Below is a figure with explanations:

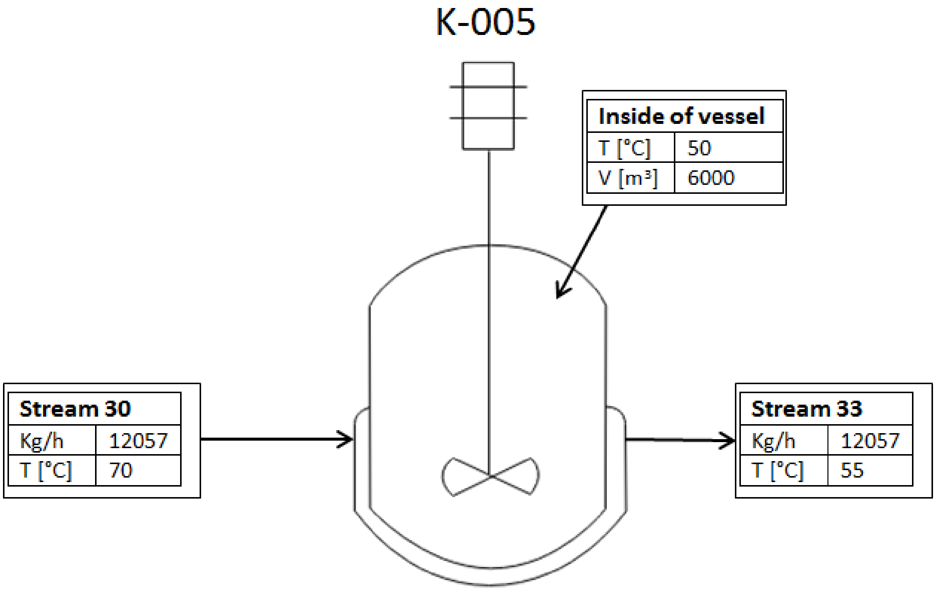


Figure 17: Mass balance of water heating loop in hydrolysis vessel

2.2.2.3 Fermentation vessel K-007

In the vessel for fermentation, the calculations remain the same. Specific heat capacity of water will be 4180 J/kgK (specific heat capacity varies according the temperature and pressure, but on the advice of the supervisor in this case was simplified). The temperature of the vessel inside 30 °C, the entering temperature in the jacket 50 °C, and at the outlet 40 °C. The volume of the vessel is changed according residence time, which is equal to 69 hours. [17]

Volume is:

$$V = \frac{250000}{1000} * 69 = 17250\ [m^3] \approx 18000\ [m^3] \qquad (2.2.2.3\text{-}1)$$

Thus, the volume is extremely large, but this number is the sum and in a real process it is necessary to divide this volume into several vessels, three or more.

Further mass flow is calculated:

$$m' = \left(\frac{35*18000}{4180*10}\right) * 3600 = 54258\ \ [\frac{kg}{h}] \qquad (2.2.2.3\text{-}2)$$

Below is a figure with explanations:

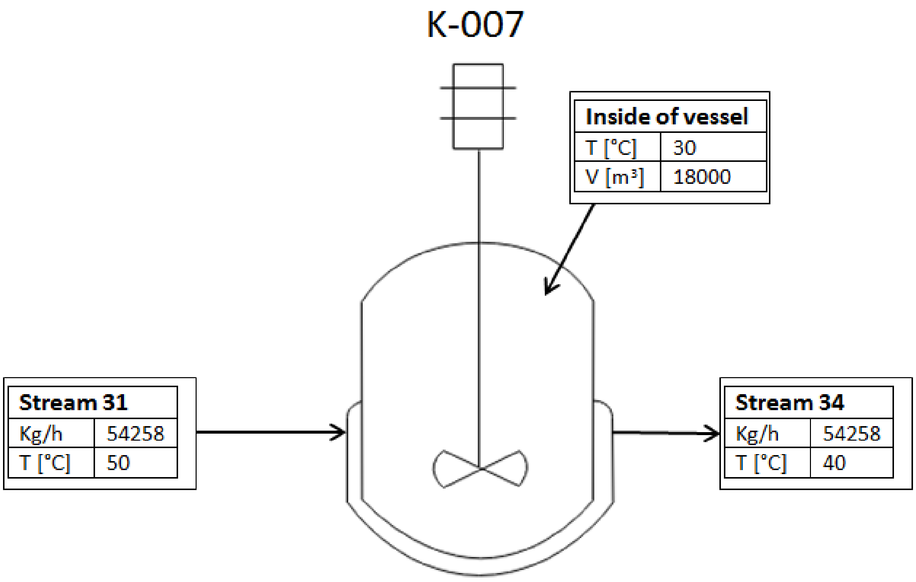


Figure 18: Mass balance of water heating loop in fermentation vessel

2.2.2.4 Collection water tank T-002

The mass flow rate of the collector tank (Figure 19) is the sum of the flows entering into it, which equals the out stream. The size of the tanker was calculated taking into account the daily work. That is, the volume flow rate per hour is multiplied by 24 hours. Thus, this tank is filled during the day. The temperature inside the collection tank is calculated according the equation:

$$Q = m'_{35} * Cp * (T_{35} - T_0) = \sum(m' * Cp * (T_1 - T_0))\ [kW] \qquad (2.2.2.4\text{-}1)$$

Temperature in stream “35” which is going out is equal the temperature inside of tank. Therefore temperature is:

$$T_{35} = \left(\frac{m'_{33}*Cp*(T_{33}-T_0)+m'_{34}*Cp*(T_{34}-T_0)}{m'_{35}*Cp}\right) + T_0 \qquad (2.2.2.4\text{-}2)$$

$$T_{35} = \left(\frac{12057*4180*35+54258*4180*20}{(12057+54258)*4180}\right) + 20 = 43\ [°C] \qquad (2.2.2.4\text{-}3)$$

The size of collector water tank is:

$$V = \frac{12056+54258}{1000} * 24 = 1591 \approx 1600\ [m^3] \qquad (2.2.2.4\text{-}4)$$

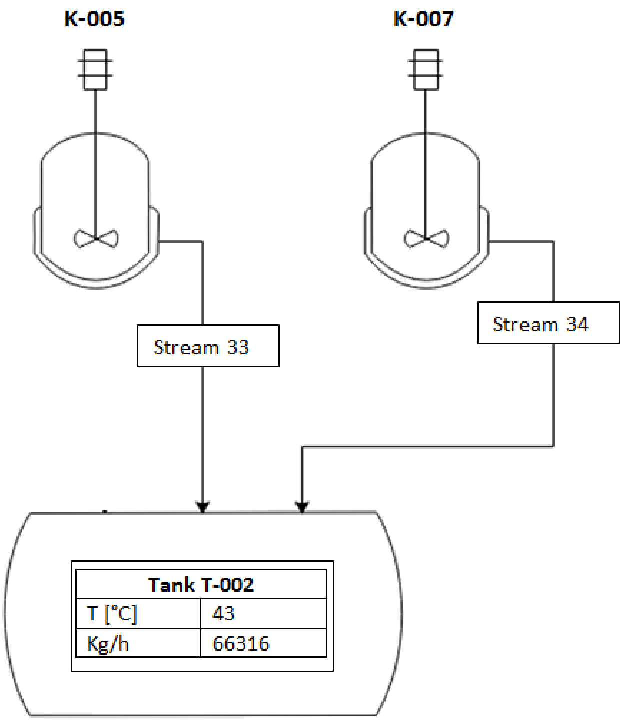


Figure 19: Mass balance of water heating loop in collection tank T-002

2.2.2.5 Distribution water tank T-003

The mass flow rate of the distribution tanker (Figure 20) is the sum of the outflows from it, which are equal to income stream “35” or “28”. The size of the tank is equal to tank for collection of water (T-002), because the mass flow rate is same. The temperature inside the distribution tanker is the average between the out streams and income streams. This tank is equipped with electric heaters that warm the water to the required temperature. This tank will be filled either once a day by the flow of water from outside the production or also reuses the water by benefiting from the connection between the collecting tanks. If distribution tank reuses water from jacket, temperature will be the same as in stream.

Temperature inside of distribution tank by filling of outside water is:

$$Q = m'_{28} * Cp * (T_{28} - T_0) = \sum(m' * Cp * (T_1 - T_0))\ [kW] \qquad (2.2.2.5\text{-}1)$$

$$T_{28} = \left(\frac{m'_{30} * Cp * (T_{30} - T_0) + m'_{31} * Cp * (T_{31} - T_0)}{m'_{28} * Cp}\right) + T_0 \qquad (2.2.2.5\text{-}2)$$

$$T_{28} = \left(\frac{12057 * 4180 * 50 + 54258 * 4180 * 30}{(12057 + 54258) * 4180}\right) + 20 = 54\ [°C] \qquad (2.2.2.5\text{-}3)$$

This result shows the necessary temperature inside the tank. However, the stream "28" enters the tank at a standard temperature of 20°C, and further heating will occur as mentioned above by a heater coil.

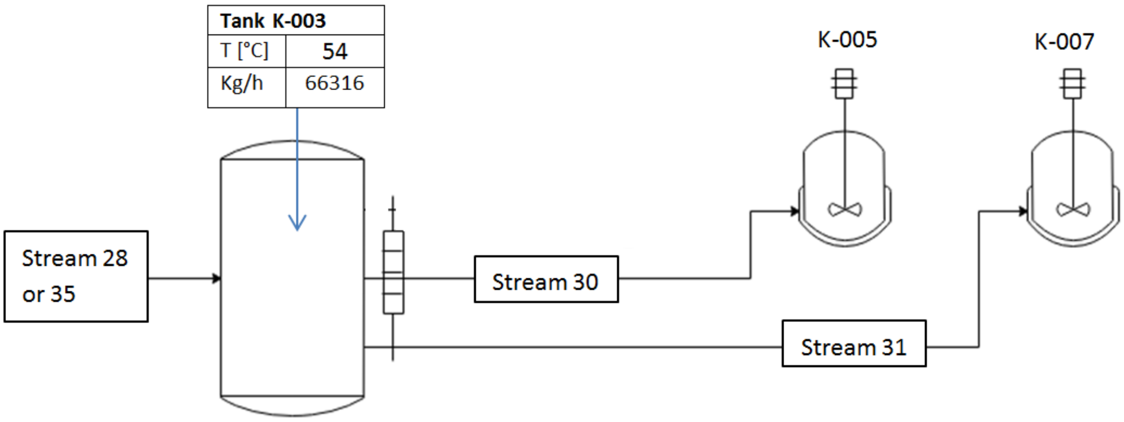


Figure 20: Mass balance of water heating loop in distribution tank

2.2.2.6 Heating oil tank (T-004)

Since the heating oil tanker serves only for the preheating of one vessel, its volume is very small, we take the same volume as in the vessel through which it transports oil. The heating oil in the tanker that flows through the stream 36 is heated up to high temperatures with the help of equipped heating coils. The mass flow will be equal to stream 29 and 32.

For more information see appendix B.

2.3 Energy balance

Energy balance is all processes within the chain associated with the energy economy. The purpose of this balance is to analyze the emergence, transformation and movement of energy within the process in detail. The main sense of this balance is the same as for mass balance that nothing can disappear and appear just like that. This balance is the explanation of the first law of thermodynamics. However, the measurement of energy is often more complicated because energy has the property of being split into heat, dust or noise. Based on this analysis, it is possible to calculate the required amount of energy and how this can be improved. In this example, heat is used as energy.

As mentioned above, calculations are created in excel (Appendix “B”).

The balance is calculated thanks to heat transfer equation.

$$Q = m' * Cp * (T_1 - T_0)\ [kW] \tag{2.3-1}$$

Not all equipment will be analyzed, only those in which there is energy exchange, that means, heat transfer. This equipment is vessels in which there are heating or cooling coils, as well as all heat exchangers. In this production, it is:

- K-004, K-006, K-008……this storage vessels have cooling coil
- K-011……………………distillation column
- W-001, W-002…………..heat exchanger
- T-001……………………distribution tank

2.3.1 Storage vessel K-004, K-006 and K-008

These vessels collect the sample after pretreatment, hydrolysis and fermentation. Since the temperatures decrease after each process, the sample cannot simply be transferred to a subsequent vessel. In order to cool the sample in the vessels are installed coils for cooling. These coils are decrease temperature to the required for the next process. For example, after pretreatment, the temperature of the sample is 195 °C, and for the subsequent hydrolysis process, the required temperature is 50 °C, thus it is necessary to reduce the temperature to 145 °C and etc. The transfer of heat for these vessels is calculated.

For K-004 heat transfer:

$$Q = 66{,}63 * 4180 * (195 - 50) = 40388425\ [W] = 40388\ [kW] \tag{2.3.1-1}$$

For K-006 heat transfer:

$$Q = 67{,}3 * 4180 * (50 - 30) = 5626525\ [W] = 5626\ [kW] \qquad (2.3.1\text{-}2)$$

For K-008 heat transfer:

$$Q = 67{,}06 * 4180 * (30 - 20) = 2803232\ [W] = 2803\ [kW] \qquad (2.3.1\text{-}3)$$

2.3.2 Distillation column K-011

In this column, the sample heats from a normal temperature of 20 °C degrees to 80 °C. Thus heat transfer:

$$Q = 61{,}16 * 4180 * (80 - 20) = 15341395\ [W] = 15341\ [kW] \qquad (2.3.2\text{-}1)$$

2.3.3 Heat Exchanger W-001 and W-002

The W-001 heat exchanger is used to transfer ethanol from the gaseous state to the liquid. In this process, there is no change in the temperature of ethanol, but only a change in its form. Therefore, the heat transfer equation will consist of latent heat and mass flow. Latent heat is also energy that the system gives or takes, while not changing the temperature, but changing its phase. The latent heat varies depending on the material, for ethanol it will be equal 846 [kJ/kg]. [21]

$$Q = m' * \Delta h^{evap} = 2{,}33 * 846 = 1976\ [kW] \qquad (2.2.3\text{-}1)$$

The second heat exchanger W-002 is used to preheat air for drying. Specific heat capacity of air approximately is 1 [kJ/kgK]. [22]

$$Q = 55{,}55 * 1000 * (100 - 20) = 4444444\ [W] = 4444\ [kW] \qquad (2.2.3\text{-}2)$$

2.3.4 Tank T-001

In this tank, the water is cooled from temperature of 80 °C degrees to 20 °C. Thus heat transfer:

$$Q = 60{,}57 * 4180 * (80 - 20) = 15193137\ [W] = 15193\ [kW] \qquad (2.2.4\text{-}1)$$

2.4 Economic calculations

Economic balance focused on our budget, which is show how to realize production. This involves with all prices of equipment, construction etc. The production was based on 24 million litters per year (18 842 400 tonne). We know that price of 1 gallon of ethanol (for our production 3.78 litters) varies from 1 $ to 2 $. We can take the average price like 1.5 $. So for 1 ton of ethanol we get 505 $.

It could be seen in appendix "D" that in fixed capital investment takes into account the equipment's, utilities and other fixed costs. The average price for equipment were founded and summed it up, the amount is 26 000 000 U.S. $. Also to this I added things like bills for various types of documents, preparation for construction, electricity and water, it is approximately 20% from 26 mln. $. In the end it give us 31 200 000 U.S. $. Also in this price were included such expenses as laboratory experiments, testing and installation of equipment. [23]

Also in economic calculations, an important factor is included as operating cost. These costs are the activity of production, that is, the necessary resources for production and resources for the operation of the equipment. In this thesis, this amount is 460 U.S. $ per ton of material and media. This can be divided so the price for the straw, water, heating oil, enzymes and yeast. On the advice of my supervisor, I learned that about 30% of the fix capital investment is spent on energy. This shows us that 9 360 000 $. per year will be spent on energy for maintaining equipment.

The calculation of the equipment was carried out using a factorial method, which has a 30% error. This method is based on equation:

$$C_e = a + b * S^n \tag{2.4-1}$$

For more details see reference “23” and appendix “D”.

On the table below, the price of equipment were shown.

Name	**Number**	**Parameter**	S_{lower}	S_{upper}	**a**	**b**	**n**	**S**	**Cost**
Storage Vessel (cone roof)	K-001	Capacity, m3	10	4000	5700	700	0,7	3000	195844
Vessel (cone roof)	K-002	Capacity, m3	10	4000	5700	700	0,7	150	29054
Mixing vessel (Homogenization)	K-003	Capacity, m3	0,5	100	14000	15400	0,7	240	727951
Vessel (cone roof)	K-004	Capacity, m3	10	4000	5700	700	0,7	6000	314590
Mixing vessel	K-005	Capacity, m3	0,5	100	14000	15400	0,7	6000	6809581
Vessel (cone roof)	K-006	Capacity, m3	10	4000	5700	700	0,7	18000	672183
Mixing vessel	K-007	Capacity, m3	0,5	100	14000	15400	0,7	18000	14676617
Vessel (cone roof)	K-008	Capacity, m3	0,5	4000	5700	700	0,7	300	43639
Vessel (cone roof)	K-009	Capacity,m3	0,5	4000	5700	700	0,7	250	39093
Vessel (cone roof)	K-010	Capacity,m3	0,5	4000	5700	700	0,7	150	29054
Column	K-011	Diameter,m	0,5	5	100	120	2	5	3100
Vessel (cone roof)	K-012	Capacit,m3	0,5	4000	5700	700	0,7	20	11399
Tank (cone roof)	T-001	Capacity,m3	0,5	4000	5700	700	0,7	2700	182325
Tank (cone roof)	T-002	Capacity,m3	0,5	4000	5700	700	0,7	1600	128156
Tank (cone roof)	T-003	Capacity,m3	0,5	4000	5700	700	0,7	1600	128156
Tank (cone roof)	T-004	Capacity,m3	0,5	4000	5700	700	0,7	240	38152
Heat Exchanger	W-001	Area,m2	1	180	1100	850	0,4	33	4542
Heat Exchanger	W-002	Area,m2	1	180	1100	850	0,4	55	5322
General conveyor	H-001	length, m	10	500	23000	575	1	30	40250
General conveyor	H-002	length, m	10	500	23000	575	1	30	40250
Screw Pump	P-001	kg/h			8000				9680
Screw Pump	P-002	kg/h			8000				9680
Screw Pump	P-003	kg/h			8000				9680
Screw Pump	P-004	kg/h			8000				9680
Pump	P-005	L/s	0,2	500	3300	48	1,2	61	9962
Pump	P-006	L/s	0,2	500	3300	48	1,2	1,3	3366
Pump	P-007	L/s	0,2	500	3300	48	1,2	59	9701
Pump	P-008	L/s	0,2	500	3300	48	1,2	0	3300
Pump	P-009	L/s	0,2	500	3300	48	1,2	0	3300
Pump	P-010	L/s	0,2	500	3300	48	1,2	60	9832
Pump	P-011	L/s	0,2	500	3300	48	1,2	0,3	3311
Pump	P-012	L/s	0,2	500	3300	48	1,2	0,2	3307
Pump	P-013	L/s	0,2	500	3300	48	1,2	0,2	3307
Pump	P-014	L/s	0,2	500	3300	48	1,2	0,2	3307
Ventilator	P-015	m3/h	200	5000	4200	27	0,8	2630	18900
Ventilator	P-016	m3/h	200	5000	4200	27	0,8	5000	28778
General Mills	Z-001	tonne/h	20	400	400	9900	0,5	22	46835
Centrifuge	F-001	Power, kW	2	20	37000	1200	1,2	20	80693
Belt Dryer	D-001	area,m2	11	180	-7400	4350	0,9	100	267066
Burner	B-001	Duty, MW			180000				217800
Rectification & Purification	-	Diameter,m							100000
Sum									25067646,3

Table 9: Capital cost of equipment

Additionally: Calculation of equipment

To calculate the cost of the equipment, we specify a property "S" that has its limits. However, in the table above, some equipment went beyond these limits, such as vessels for hydrolysis or fermentation. This can be explained by the fact that in real production several vessels will be used for each process, but the process flow diagram uses one symbol for control.

The price of the columns was taken from online stores. The price is estimated from 10 to 500 thousand $. After discussion with the supervisor it was decided to round off the amount to 100 thousand $.

The heat exchanger W-001 prices are considered taking into account their heat transfer area. This size was expressed by the equation:

$$Q = A * u * dT \tag{2.4-2}$$

$$A = \frac{Q}{u * dT} \tag{2.4-3}$$

Where:

- A……..heat transfer area [m^2]
- u……..heat transfer coefficient [W/m^{2}K]

$$A = \frac{1976*1000}{1000*60} = 33\ [m^2] \tag{2.4-4}$$

Thus, the heat transfer rate for this heat exchanger was calculated in previous chapters, and the heat transfer coefficient was obtained from the supervisor. The next heat exchanger was calculated in the same way.

2.4.1 Payback time

The calculation was carried out in exile, under the name economy (app. "F").

Taking into account various data, it is possible to calculate the payback time. Of course, it is depends on many factors and an error is inevitable. The appendix "F" lists the economic calculation taking into account the given factors, which can easily be changed in order to predict the outcome of the plant. If we assume that approximately 20 operators with a salary of US $ 1000 will be involved in production. And the bank will cover all costs. The production will start to bring money and cover the loan in about 5-7 years of work. This calculation was carried out taking into account 15 years of work and a 10% discount, but the discount in reality can be less. On the graph below you can see the result.

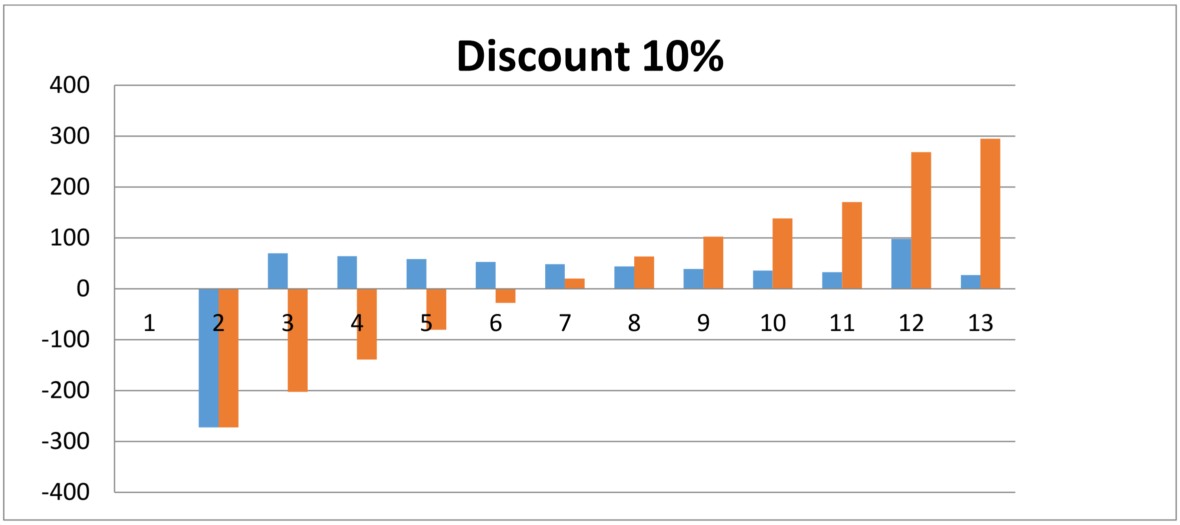


Figure 21: Payback time (discount 10%)

2.4.2 Comparison

The use of bioethanol as a fuel can reduce emissions of carbon dioxide. The reduction of CO^2 emissions from the production of ethanol in the US in 2007 is 19%. The maximum reduction in CO^2 emissions can be achieved in the production of ethanol from cellulose-containing waste (for example, forest waste, 52%) as a source of pulp and fuel in alcohol production. The theoretical maximum of the reduction of emissions is 82%, It can be achieved in the production of ethanol from the cellulosic biomass of "Panicum virgatum" millet, but there are currently no such production (2011). [9]

Comparing the production of bioethanol in this diploma work with combustion of wheat straw, it can be safely said that the emissions of carbon dioxide are 10 times less than simple combustion. Based on the mass balance calculations, CO_2 emissions are 150 grams per ton of wheat straw. And based on enclosed reference, there is amount of CO_2 1469–2098 gram per kilogram of dry straw. This is showing the profitability of this production. [24]

However, despite the fact that the amount of emissions compared to burning is much less, in our time, still the production of bioethanol does not always bring its advantages. According to the analysis of some sources, the conversion of biomass into electricity is friendlier for the climate, and also does not always benefit from the complexity of production. Since simple combustion is a simpler and faster method, bioethanol production as of utilization of the biomass is still in development. [9]

2.4.3 Building legislation

Each individual person or group in Kazakhstan has the right to construct an object that meets his needs. Somebody need to build a house, but to someone want to build a small production. The different can be materials, design and architecture - every person chooses what he needs. But one point in the construction remains unchanged - these are the documents.

According to the legislation of Kazakhstan, construction, reconstruction and even major repairs can not be realized without official permission and the corresponding package of documents.

A building permit is a document that confirms that the project documentation of your facility fully meets the requirements of the town planning plan. And only after getting of all permits, you will have the permit to the reconstruction or construction.

Many people do not pay attention to registration of documents for construction, and begin construction work without obtaining permission. This is a fundamentally wrong approach, because according to the rules, structures built without the accompaniment of relevant documentation are considered illegal and can even be demolished. In such cases, the developer can pay a huge costs - not counting the funds already invested in the construction and materials, also they have to pay considerable fines and dismantle the already constructed facility. In addition, even if it is possible to avoid demolition, the ignor of regulatory legal documents in the construction can negatively affect the procedure for its clearance, when the construction will be completed.

The building permit is issued by the Architecture and Urban Planning Department after submission of an application and package of documents, which includes:

- Akimat(governor) has to give the decision on granting a land plot for construction or permission to use the land plot already owned by you.
- Materials of engineering surveys of the site where construction is planned.
- Technical conditions for connection to sources of engineering and municipal services
- Architectural and planning task (APT).
- Task for design (development of project documentation).

After receiving the permits for construction, finally, you can conclude an agreement with the contractors and proceed directly to the construction. [25]

2.4.3.1 Akimat (governor) decision

For the receiving this certificate, you must provide the following documents to the registration authority:

- passport or other identity card
- invoice of payment of state duty;
- a title document that confirms the applicant's permit to the land plot. This may be a certificate of inheritance, an order to allocate a plot of land or an order to provide land, a contract of sale, a court decision on the recognition of ownership and other documents;
- cadastral plan of the land plot;
- an application for state registration of a piece of land on the right of ownership.

2.4.3.2 Engineering surveys

Engineering surveys for construction are a kind of construction activities which providing a study of natural and man-made conditions of territor of the projected construction, is predicted of the interaction of these objects with the environment, justification of their engineering protection and safe living conditions of the population.

The engineering survey for construction includes the following main types: [26]

- engineering-geodetic
- engineering-geological
- engineering-hydrometeorological
- engineering and environmental surveys
- exploration of soil building materials and sources of water supply based on groundwater.
- Etc.

2.4.3.3 Technical conditions

Technical conditions is the document necessary for obtaining permission to connect all types of communications (water, sewage, electricity, gas, etc.) This is a set of requirements and technical standards about relation to the object under construction, the features of its design, construction and operation. The technical conditions contain all the information necessary for connection: circuits and connection points, energy calculations, etc.

2.4.3.4 APT

APT (Architectural and planning task) is one of the main normative documents that must be obtained before the construction starts. The APT contains all the requirements that must be met when building up: to the destination, the main parameters, the location of construction sites, mandatory environmental, technical, sanitary and other conditions stipulated by law and local building regulations. In addition, the architectural and planning task includes the requirements for the protection of historical and cultural monuments, the environment, as well as for the observance of the legitimate rights of citizens and legal entities whose interests may be affected during construction on this site.

2.4.3.5 Development of project documentation

Buildings design is activity which is creating a set of documentation designed to build a particular facility, its operation or repair. Designing is carried out with observance of all GOSTs, safety requirements, normative documents and other standards. Strictly licensed organizations are engaged in design.

Conclusion

In this thesis, the capabilities of Kazakhstan in the production of bioethanol were reviewed.

The first chapters describe the situation with waste in Kazakhstan. As a result, it can be said that the country has great problems with waste and pollution, which will certainly lead the problems in the future, but Kazakhstan also has sufficient potential in developing of processing and converting this garbage into energy. It was also mentioned that the process of bioethanol production had already been implemented, but it failed, which showed the basics problems in country. These problems are the general ignorance and nescience of citizens, government in the processing of garbage and control over the environment. My advice is to create the necessary committees which can controlled this area, studied and took the first steps in solving this problem.

The second chapter makes it clear that the production process has already been sufficiently studied and has already been applied in many countries. Raw materials for bioethanol can vary greatly depending on the capacity of the agrarian industry. The principle of ethanol production was also explained step by step. One from the many variations in production was selected with included parameters, such as time, temperature, and so on.

In the third part, a theoretical model for the production of ethanol from wheat straw was developed by creating a process flow diagram and all calculations adjacent to it. The diagram does not set off real details, since it does not capture small parts. The amount of produced ethanol was chosen, it is 100 000 liters per day, which required 523 400 kilograms of straw. According to these data, an analysis of mass balance and the economical balance were carried out. As a result, theoretical production will begin to yield revenue after 5-7 years of work.

In the end, I wanted to thank all those who supported me and helped me in this work. I also wanted to say that I received a knowledge that showed me the importance of this area of study and how this is realized in reality.

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List of symbols

Q	heat transfer rate	(kW)
Cp	specific heat capacity	(kJ/kgK)
T	temperature	(°C)
dT	temperature difference	(°C)
V	volume	(m^3)
E	specific heat loss	(W/m^3)
$m^{’}$	mass flow rate	(kg/h)
$V^{’}$	volume flow rate	(m^3/h)
t	time	(hour)
ρ	density	(kg/m^3)
$\Delta h^{evap.}$	latent heat of evaporation	(kJ/kg)
A	heat transfer area	(m^2)
u	heat transfer coefficient	(W/m^{2}K)

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