CZECH UNIVERSITY OF LIFE SCIENCES

FACULTY OF TROPICAL AGRISCIENCES

Department of Sustainable Technologies

Use of cotton bushes and tree branches (apricot tree) as energy source in Tajikistan

Dissertation Thesis

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Prague 2020

Declaration

I hereby declare that I have done this thesis entitled "***Use of cotton bushes and tree branches (apricot tree) as Energy source in Tajikistan***" independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 8th of April 2020

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Sayfullo Akhmedov

Acknowledgements

I would like to thank to all persons and institutions everyone who helped me during the research and preparation of this thesis. My special appreciation to my supervisor doc. Ing. Vladimir Krepl, CSc. For his instruction, direction, consultation and very useful suggestion. I would like to say my special thanks to doc. Ing. Bc. Tatiana Ivanova, Ph.D. for her time, significant help, academic support throughout the whole research and expert consultation and Ing. Michel Kolarikova, Ph.D. for organizing the laboratory test in Research Institute of Agriculture Engineering and Bioenergy Centre. My further appreciation to Ing. Alexandru Muntean for his very helpful advice, help assistance during the experiments in laboratory. As well my special appreciation to Ing. Tereza Pilarova, Ph.D. for her significant help with questionnaire, data process and statistical analyzing. And further thanks to director of research institutes of Gardening and Horticulture in Sughd region candidate of agriculture science Boboev Mahmudjon and director of research institute Melioration and Irrigation in Sughd region candidate of agriculture science Gaybullo Akhmedov for their help with collecting and transportation of biomass to Czech University of Life Sciences. I could never have understood this Study without their contributions.

Also, I would like to say my grateful thanks to my family and friends who support me during my study in CZU.

The presented research was support by Internal Gran Agency (IGA) of the Faculty of Tropical AgriSciences CZU Prague, research grant numbers 20165012, 20175011, 20185011 and 20195010. As well Erasmus Mundus A2 – Partnership CASIA III Cohort II (Central Asia Student International Academic exchange with EU)

Abstract

One of the main issues in Tajikistan is the lack of access to energy in rural areas during the winter season. In several nations, the negative environmental effect associated with fossil fuel burning has initiated the development of solid biofuels made of specific biomass as an alternative to conventional fuels. The advantages of renewable biofuels are the ability of briquettes and pellets generated or mixed with raw materials from various agricultural waste. Tajikistan's aim is to achieve independence in energy matters. Tajikistan is an agricultural country that provides the rural communities with food and jobs, the main source of income for the majority of the population especially for rural area.

In 2017, about 61,617 hectares of apricot were cultivated, and 187,500 ha of the cotton have been harvested according to the TAJSTAT, which annually accumulates a huge quantity of pruning waste and cotton stalks. The apricot tree pruning is one of the most effective agro-technical treatments that provides for at least once a year. Around 156 trees grow in one hectare by the Institute of Horticulture in Tajikistan and approximately 15–20 kg of branches are available every year after pruning each tree and 100,000 cotton bush is available in one hectare of the land for use as biomass, which is typically misused. The main objective of this study is to assess the possibility of using the raw materials from cotton bushes and apricot branches for briquettes and pellets analysis of their properties through laboratory measurements and estimation of the energy yield and potential from this material.

Key words: cotton bush, apricot tree branches, briquettes, pellets, agriculture, Tajikistan, renewable energy

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LIST OF SYMBOLS AND ABBREVIATIONS

ADB	Asian Development Bank
ASSR	Autonomous Soviet Socialist Republic
CAPS	Central Asia Power System
CIS	Commonwealth of Independent States
CZU	Czech University of Life Sciences in Prague
CV	Calorific Value
DU	Mechanical Durability
FAO	Food and Agriculture Organization
GCV	Gross Calorific Value
GDP	Gross Domestic Product
GHG	Greenhouse Gas
Ktoe	Thousand tons of oil equivalent
MC	Moisture content
NCV	Net Calorific Value
RES	Renewable Energy Sources
TAJSTAT	The Statistical Agency under the President of the Republic of Tajikistan
TJS	Tajik somoni, Tajikistan National Currency
TJ	Terajoule
UN	United Nation
UNDP	United Nation Development Program
UNECE	United Nations Economic Commission for Europe
USSR	The Union of Soviet Socialist Republics
SSR	Soviet Socialist Republic
%	Percent
cm	Centimeter

g	Gramm
h	Hour
kg	Kilogram
mm	Millimeter
t	Ton
j	Joule
MJ	Megajoule
C	Carbon
N	Nitrogen
H	Hydrogen
Atm	Atmosphere
PHT	Postharvest treatment
CGT	Cotton gin trash
HPP	Hydropower plant

1 Introduction

An increasing awareness of the negative environmental cost associated with the combustion of fossil fuels and concerns over the geopolitical instability of the main oil-producing regions is driving the development of renewable energy sources and biofuels. Use of solid biofuels made of different types of biomass became perspective alternative to conventional fuels in many countries. Such positive indicators as low cost of the final product that meets the quality of standards, not capital-intensive production, the possibility of producing briquettes/pellets from almost any agricultural waste or combination of raw materials are undoubted advantages of biomass-based fuels.

During the winter Tajikistan has significant electricity shortages in rural area. Deficit caused by a high demand for heating and cooking in winter. Loss of imports of electricity since 2009, cuts in natural gas imports and dependence on a hydropower system that has limited capacity in the winter due to low river stream. All others are run-of- river plants that experience low flows in the winter. Nurek power plant, which produce more than 60% of its installed capacity, is the main of Tajikistan's power system. The main challenges for Tajikistan's energy sector, which is depended on energy imports during the winter, are: to increase energy supply through better exploitation of hydropower and other renewable energy sources such as wind, solar and biofuels.

The Tajikistan's goal is to reach energy independence and is identified in many existing programs and documents including the National Development strategy. One of the main targets for the energy part is to gives table and high-quality approach to energy for the entire population, industries and services, and the efficient use of all available energy (hydro, solar, wind and biomass) in order to lower the poverty.

Tajikistan is agrarian country and agriculture has big influence in economy and work labor, more than 53% of population works in agricultural sector (FAO 2018). Within the agricultural sector of Tajikistan, cotton accounts for 60% of agricultural output and horticulture, gardening also one of the main sectors in agriculture. Cotton remains as a major agricultural industry in the Republic of Tajikistan. A fiber as the main products of cotton is a valuable commodity for export and brings huge income to the economy of the country. According to the Ministry of Agriculture of Tajikistan, 199,400 hectares of lands have been allocated to cotton cultivation in the year of 2014. The cotton industry has a big potential and strategic importance for the development of the national economy of the Republic of Tajikistan. The Government of the Republic of Tajikistan and international financial institutions are helping to farmers to develop the cotton production. Investment projects of state institutions „Project Management Centre to repay debt cotton farms and sustainable development of the cotton industry“and „Project Management Centre for Rural Development“ directed its activities to support the agriculture and cotton industry. Plenty of unused cotton stalks residual biomass could be effectively utilized for winter heating in rural areas.

During the Soviet Union period in Tajikistan many hectares of orchards such as apricot, vineyard has been cultivated. Gardening and horticulture are also having potential role to economy and labor market. Export of the dry fruits mainly apricot helps to improve living standards of population especially in rural area also has economic value. Main importer of dry apricots from Tajikistan are Russia and Kazakhstan. In order to improve the production of apricot it's necessary agro – technical treatment (pruning the tree), which can be done once, twice per year. After the pruning the apricot orchards accumulates big amount of agricultural waste as wooden biomass.

The solution of the energy problem and agricultural waste utilization can be using the cotton bushes and apricot tree branches for energy purpose, in the form of briquette and pellet as renewable source of energy in Tajikistan.

Biomass has major role in rural life especially in energy sector. Beside that it helps to the economy the chance to create new job places and source of income to rural population. It also helps to environment and waste management in the country. Reports shows that Tajikistan has potential to generate 2 billion kWh/year of electricity from the biomass. Approximately three quarters of population use biomass for cooking and heating in their daily use (REEEP 2012). Cotton bushes and apricot tree branches a completely renewable source of energy; besides that, we can convert them into briquettes and pellets by utilization method and it is easy to transport and store.

Due to facts the cotton bushes and apricot tree branches are the most accessible type of biomass in Tajikistan it is necessary to do deeper research of the possibility of using them for the biofuel production especially in the form of briquette and pellets. The main focus of the research was to investigate and assess physical, chemical and mechanical properties of pellets and briquettes produced from cotton wastes and apricot tree branches.

2 Literature review

Presented thesis mainly divided in two parts theoretical and practical (laboratorial experiments). In theoretical section reviewed the scientific books and journals, published articles and dissertations, reports from the international organizations and all other available electronic sources. In individual chapters reviewed and cited available data. Mainly paid attention to the part of economy, agriculture part and energy situation in the country. Since Tajikistan is agrarian country bigger portion of population are living in rural area and accessibility of the population to the energy. Also, special attention to the using of an agricultural waste as renewable energy in rural area as form of briquette and pellets.

Practical part of the thesis is mainly focused on laboratory works based on EU and ISO standards. Special attention was made to the chemical and physical properties of materials. Especially to the Gross and Net calorific value of the biomass.

2.1 Country review

Republic of Tajikistan located in Central Asia (CA). The territory of Tajikistan is 143,100 km^2. Tajikistan is mountainous and landlocked country; neighbors are Kyrgyzstan, Afghanistan, Uzbekistan and China (see Figure 1). Population of Tajikistan over 8.7 million (World Bank, 2016). The ethnic groups of the country consist of 80 percent of Tajiks, Uzbeks 12 percent, 3 percent Russian and 5 percent other including, Tatars, Kyrgyz and Koreans (GoT). Following its ethnic diversity there is also religious and linguistic diversity. The official language is Tajik, which Persian based. About 80 percent of the population is Sunni Muslim, and the rest are Ismailia, Orthodox and Christians. 73 percent of the population is living in rural area, with mostly involved in the agricultural sector. Mainly, the agricultural production is based on irrigation.

Figure 1. The map of the Republic of Tajikistan

Source: (One World - Nations online 2019)

The topography of the Tajikistan is mountainous with elevations varying between 300 and 7,495 meters above sea level. Mountains applying to the tallest ranges of Central Asia make up 93 percent of the total area of the country. Geographically, the western part of the Tajikistan is wedged by desert and semi-desert areas of the Touran lowlands that gradually turn into foothills. In the east, the country territory abuts with gigantic mountain ranges and Central Asian highlands – Tibet and Tien-Shan. This geographic situation accounts for a wide variety of natural conditions. Tajikistan reach of the lake and rivers. There are about 947 rivers longer than 10 kilometers with a total length of more than 28,500 kilometers. The rivers account for 60 percent of all water-resources of central Asia (World Bank open source). Tajikistan is mostly mountainous, about 50 percent of the country with a height of 3,000 meters above sea level and higher. Out of the total area of 14.1 million hectares (ha), only 4.3 million hectares is agricultural land and only 824,000 hectares is arable land. Administratively, country is divided into four main regions (viloyat): Sughd, Khatlon, Gorno-Badakhshan (GBAO) and Regions of Republican Subordination (RRS) including Dushanbe, the capital city.

According the Agency for hydrometeorology The Committee of Environmental Protection under the Government of the Republic of Tajikistan. Wide valleys and valleys with a height of up to 1000m are the primary areas of agriculture and cotton. These include the south-western part of the country: Hissar, Vakhsh, Kulyab valley and the Ferghana Valley with its surrounding plains, Sughd region.

For wide valleys and valleys are characterized by elevated temperature in summer, when the summer heat prevails depression. In summer it is characterized by a clear and hot weather, when the maximum temperature can reach 43-47 ^{0}C. The average monthly temperature of the hottest month of July is 28-30 ^{0}C. Cold period is characterized by the invasion of cold Arctic air, in which even in the southern republics of the public temperature on separate days can drop to -24-30 ^{0}C. The average monthly January temperature mainly positive 0.3 - 2.5 ^{0}C, but in certain northern parts (Khujand), it can fall below 0 ^{0}C. A characteristic feature of this zones are use more temperature variations with frequent transitions it through 0 ^{0}C. The last spring frost for most areas cease to the end of March, the first autumn frosts occur in the second half of October. For valleys of southwestern Tajikistan is characterized by the longest frost-free period of 260 days.

The climate of the Tajikistan contains a ramification of temperature levels, moisture situations, precipitation individual, and the intensity of solar radiation. Depending on the elevation, average annual temperatures may additionally vary from + 17 to – 6 °C. Most and minimal temperatures may vary from +47 to -63 °C. common annual quantity of atmospheric precipitation constitutes from70 to 1,800 mm and extra (Kayumov & Kabutov 2016).

Tajikistan is an agrarian country. Agriculture is one of the main and important sources of income of the population. Agricultural division provides food and employment of the community, especially in rural areas. The agriculture part provides for about 60 % of employment and 30 % of GDP. The agricultural sector of Tajikistan is based on the production of cotton, cereals (mainly wheat), potatoes, vegetables, fruit crops (grapes, apricot, peach and others) and livestock products. About 70 % of the land used for agriculture is irrigated. Forest cover is very scanty (3-5 %). Led to the creation of a new category of farms, known as private farms. The total agricultural production has increased significantly since the mid-1990s to the present.

2.1.1 Economy of the Republic of Tajikistan

In Central Asia Tajikistan remains is one of the poorest country (World Bank 2013). Based on (Asian Development Bank 2018) in 2015 31.3 % of the population lives below the national poverty. After independency Republic of Tajikistan, country faced to huge economical problem. Due to economic system, during the Soviet Union Tajikistan and other member of Soviet countries were dependent to the Moscow. And Tajikistan was highly agrarian and light industry country. Main part of the economy was agriculture and civil war after independency were destroyed the light industry and made big negative influence on the agriculture sector.

In 1991, the Union of Soviet Socialist Republics (USSR) broke up, Tajikistan as all other former Soviet countries had seen massive movements of migration of workers. Unemployment became one of the main problems in socio – economic sector due to the civil war. Many people start to immigrate to the bigger city even to the different country. In rural area agriculture production was the only source of income for the population.

In 1997 was signed the peace agreement between Government of Tajikistan and opposition group. Since then, the situation slowly started to change to the better way. Even though, unemployment rate remains very high. Based on UNDP report only were 55 thousand people registered as unemployed in 2013 which means 2.3 % of the population was unemployed. Almost every third people in rural were unemployed in 2009 (UNDP 2015). Immigration for the young people especially in rural are became a common job, mostly left to the Russian Federation for the job search.

Money transfer from the immigrants played the major role to the economy of the Tajikistan. According to (Zotova & Cohen 2018) Tajikistan remains cash transfer – dependent country in the world, where the money transfer in 2014 was 3.8 billion US dollars which is 41.7 % of the country's domestic gross product (GDP).

Gross domestic products (GDP) of Tajikistan is growing and getting more stable. In the following graph (Figure 2) is visible the last decade of GDP of Tajikistan.

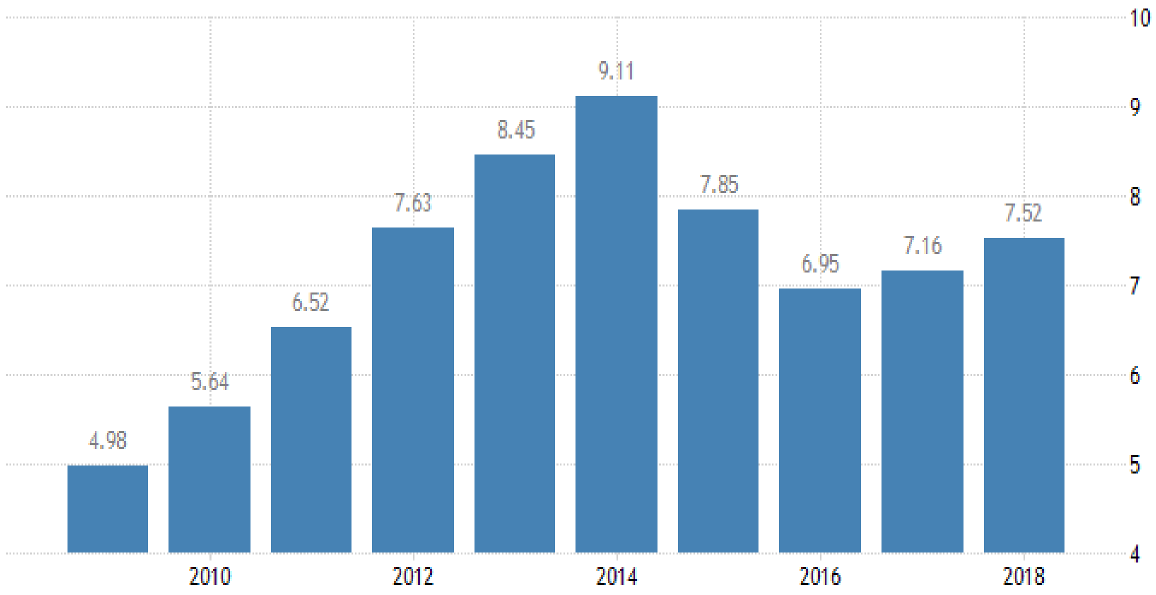

Figure 2. GDP of Tajikistan, %

Source (Trading Economics 2018)

Based on the published information data by TAJSTAT, main economic sectors in Tajikistan are agriculture, industry, trade, communication, transport, service and construction. Agriculture is one of the main and significant sectors of the Tajikistan's economy. In 2015 Agriculture had more than a quarter of Tajikistan's GDP (Legislation of Tajikistan 2019). Nevertheless, arable land in Tajikistan is limited and most of it uses for production of cotton, because cotton is one of the main exported products in agriculture. The cotton production in the national economy make a critical contribution. Cotton is a 60 % agricultural product, supports 75 % of the rural population and uses 45 % of the irrigated arable land in the agricultural sector. It is a major source of both export revenues (15 %) and tax revenues at national level (The cotton sector of Tajikistan 2007). Also, export fruits and dry fruits has one of the major products, which is going to export and has essential role to the rural population life. Mostly fruit and dry fruit products from Tajikistan are going for export to Russian Federation, Kazakhstan, EU and other countries.

In last four years in Tajikistan is visible that GDP growth yearly in agricultural, serves, construction and mainly in industry sector. Following table (Table 1) shows the GDP growth in Tajikistan.

Table 1. Tajikistan's GDP growth, by percent

Sectors	2015	2016	2017	9 months of 2018
Real GDP growth	6	6.9	7.1	7
Agriculture	0.9	1.3	1.6	0.8
Construction	2.5	2.7	0.5	1.7
Industry	1.6	2.3	3.6	2.6
Services	1.1	0.5	1.4	1.8

Source (World Bank 2018)

Industry has a decisive influence on the country's economic development and is a key element of economic industrialization and contributes to the development of national economic sector. Industry is a major production sector. In NDS-2030 (National Development Strategy), where the aim is to create scope for the transformation of national economy from agro-industrial to industrial-agrarian. The importance of the industrial sector to the national economy is highlighted (Table 2). Tajikistan is rich in metallurgical, chemical, construction and other raw materials. The growing interest of customers both inside and outside the country in high quality raw materials and goods can be met for most of the metallurgy, mining, chemical, machinery and textile companies with high export potential in short periods. Mining companies' goods are primarily for export and have high global demand (Tajik Development Gateway 2019). The share of industry in GDP for 2014 calculated 12,1 %, in 2015 - 13,3 %, and, according to the Agency on statistics under the President of Republic of Tajikistan, in 2016 this indicator already reached 15,1 % (Extractive Industries Transparency Initiative 2018).

Table 2. Production growth rate in Tajikistan by percentage

	2015/2014	2016/2015	2016/2014
All industries	113.4	116	143.2
Mining	117.9	153.3	214.24

Extraction of energy materials	90.9	119	97.80
Extraction of non-energy materials	123	156.7	236.77

Source (Extractive Industries Transparency Initiative 2018)

Another industrial sector of the Tajikistan is light industry. The sector of the light industry Republic of Tajikistan includes many related subsectors; is a major national economic sector of the Republic and provides the manufacturing of consumer goods for industrial use. Furthermore, the light industry includes cotton, knitting, furnishings and leathers processing. The proportion of the light industry in the total production volume is around 15 % in 2017 ("Business guide" 2017).

Tajikistan's government sees the textile and clothing sector as a priority sector for the country's future development. Production in these industries includes cotton fiber, fabric and cotton yarn, standard clothing and clothing with additional textile enhancements including uniforms, overalls, shirts, pants, jeans, etc. The goals of developing Tajikistan's textile and clothing industry include diversifying the export base and creating new jobs. Within the country, textile companies are processing 12,000 tons of this cotton fiber per year (Zuhurov et al. 2016).

The main economic indicators of Tajikistan are presented below in the Table 3.

Table 3. Economic indicators of Tajikistan

	2013	2014	2015	2016	2017
Population (million)	8.2	8.4	8.5	8.5	8.7
GDP per capita (USD)	1.043	1.031	807	799	777
GDP (USD bln.)	8.5	8.6	6.9	7.0	6.9
Economic growth (GDP in %)	7.4	6.7	6.0	6.9	7.1
Unemployment rate, %	2.4	2.4	2.2	2.3	2.1
Fiscal balance (% of GDP)	0.3	0.3	0.8	-1.7	-0.3

Public dept (% of GDP)	29.1	27.7	34.7	42.0	50.4
Money (annual variation in %)	18.6	3.5	12.2	56.7	36.6
Inflation rate (CPI, annual variation in %,)	3.7	7.3	5.2	6.0	6.8
Inflation rate (CPI, annual variation in %)	5.1	6.1	5.7	6.0	7.3
Policy interest rate, (%)	5.50	8.00	8.00	11.00	16.00
Exchange rate (vs USD)	4.77	5.29	6.99	7.88	8.82
Current account (% of GDP)	-10.4	-3.7	-6.9	-4.2	2.3
Current account balance (USD bln.)	-0.9	-0.3	-0.5	-0.3	0.2
Trade balance (USD billion)	-3.4	-2.5	-2.0	-1.7	-1.2
Export (USD billion)	0.6	0.5	0.6	0.7	0.9
Import (USD billion)	4.6	3.6	2.9	2.6	2.4
Export (annual variation in %)	-30.4	-8.2	8.6	16.7	30.7
Import (annual variation in %)	3.5	-21.1	-20.5	-10.8	-6.4
International Reserves (EUR)	0.5	0.4	0.5	0.6	1.1
External dept (% of GDP)	57.1	60.1	72.5	69.0	73.7

Source (“Tajikistan Economy - GDP, Inflation, CPI and Interest Rate” 2019)

Based on National Strategic Development plan for the period till 2030, Tajikistan wants to be an industrial – agrarian country. Tajikistan's highest long-term development goal is to raise the country's population's living standards based on sustainable economic development. To achieve the NDS plan 2030, the following goals have been set for the next 15 years:

1. Ensuring the energy security and energy efficiency.
2. Changing from the communication deadlock to the transit country (in term of roads).
3. Assuring food security and access to quality nutrition.

4. Expansion of productive employment.

2.2 Energy situation in Tajikistan

The last decade Tajikistan's energy sector gone through the big changes and hard time. After collapse the Soviet Union each country became independent and energy resources and energy market in Central Asia became independent. Energy corporation in Central Asia has been stopped, and gas pipelines been cut off, mainly from neighbor country Uzbekistan. And Tajikistan's economy and industry became dependent on energy import, due to lack of the energy sources in country such as gas, oil and electricity. And country's economy was unable to invest the required amount to the maintaining the energy infrastructure (World Bank 2014).

During the Soviet Union all five countries in Central Asia were part of Central Asia Power System (CAPS). That system was built to cover the required energy demand in the region. The system was capable to generate and transform the energy between countries. According to (Kayumov & Kabutov 2016) hydropower is the main basic resource in Tajikistan.

The countrywide transmission gadget of Tajikistan is an imperative part of the Central Asian energy systems. Based totally on its hydro energy potential, Tajikistan want to provide extensive amounts of energy to Central Asian nations in addition to Pakistan, India and China. Currently, the Tajik energy gadget is hooked up to electricity systems of Uzbekistan and Kyrgyzstan by 220 and 500 kV transmission lines. The new transmission line from Afghanistan is under construction and several more lines connecting Tajikistan with potential customer countries have been identified as essential for the export (Klaus Jorde & Biegert 2011). During the summertime Tajikistan has possibility to produce more energy and export them to other countries. The Tajik energy company "Barqi Tojik" had possibility to export the 3.3 TWh surplus energy to neighboring country during the summer and invest the incoming money from export to renovation the energy producers. For development the future energy export in Central and South Asia the new project CASA -1000 has started (Akhrorova et al. 2017). From this project will have benefit not only Tajikistan but also Kyrgyzstan, which has similar situation in energy sector (Halimjanova et al. 2019).

Tajikistan is landlocked country located in middle of Central Asia (CA). The mainly source of energy in Tajikistan is water (hydropower). Tajikistan has an immense potential of water resources that can be used to produce the electricity but Tajikistan using only small fraction from the potential, the 94 % of electricity in the country is produced in hydropower plants (HPPs). The Government of Tajikistan focuses on the development of new source of energy such as renewable energy and refurbishing/upgrading of existing large hydropower plants. But there are also plenty of opportunities for small hydropower plants, renewable source of energy such as solar, wind, biomass and development of including isolated grids to support decentralized energy generation (Klaus Jorde & Biegert 2011). According to (Karimov et al. 2013) there are seven main hydropower plants in Tajikistan (Table 4).

Table 4. The main hydropower plants in Tajikistan

Number	Details
1	Norak (3,000 MW, height of dam is 300 m, constructed in 1960–1980)
2	Baipaza (600 MW).
3	Golovnaya (240 MW)
4	Kayarkkum (126 MW)
5	Sangtuda-1 (670 MW, constructed in 2009)
6	Sangtuda-2 (220 MW)
7	Rogun (3,600 MW, height of dam is 355 m, constructing)

Source: (Karimov et al. 2013)

In the follow picture (Figure 3) are presented existing and prospective hydropower plants in Tajikistan.

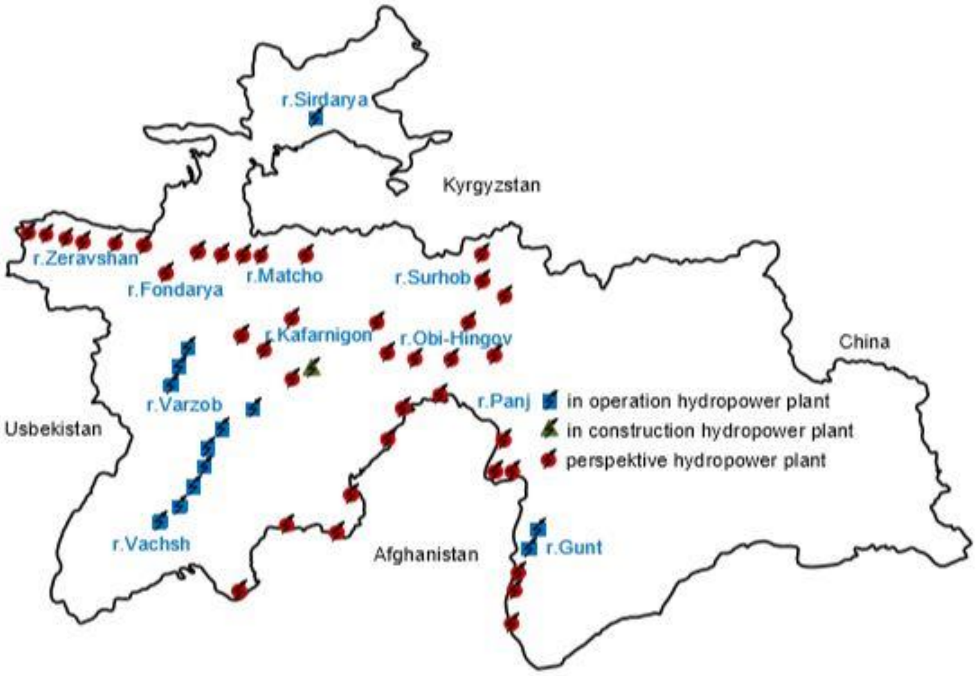

Figure 3. Map of existing and prospective hydro power plants in Tajikistan

Source (HALIMJANOVA et al. 2017)

Another issue with energy source of Tajikistan is all the hydropower plant were built during the Soviet Union era. All the hydropower plants are very old and needs big investment for modernization and efficiency, especially during the wintertime when the water levels drop down hydro power plants are not able to work in full capacity and efficiency are low. Nurek hydropower plant is one of the biggest in Central Asia, which was built in 1979. Unfortunately, over the years the reservoir of Nurek HPP became less capable due to fill up with sediments, because it’s located close to river springs.

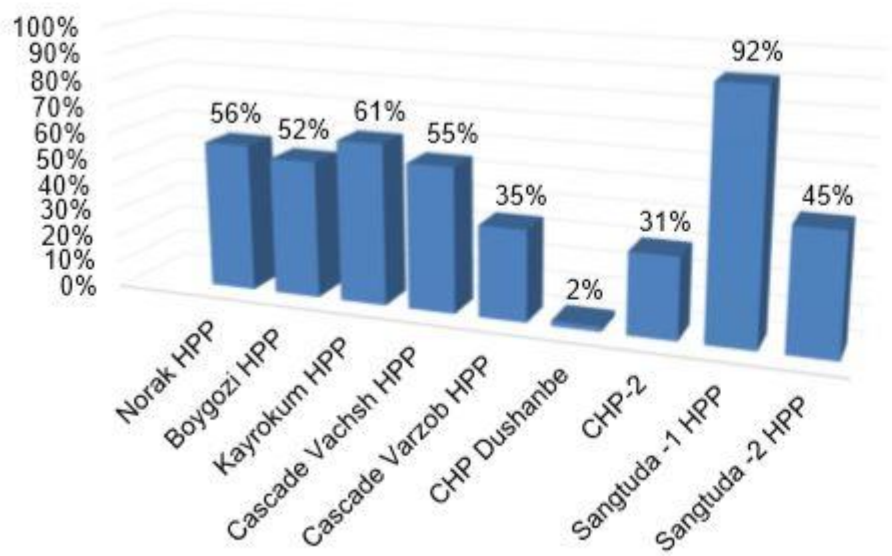

Figure 4. Power plant efficiency in Tajikistan during the wintertime

Source (HALIMJANOVA et al. 2017)

Tajikistan is struggling badly with strength crisis related in general with a deficit of conventional energy sources (oil and fuel), which adversely impacts the industrial ability and whole economic system. Energy shortages during the winter, due to decrease water flows in rivers and energy production, along with an increased demand for heating and cooking, lack of cheap alternative energy resources, create a deficit between supply and demand that effects in load shedding (Laldjebaev et al. 2018). Due to limited access to renewable source of energy, demand to the energy increases during the winter season. This condition is caused by the freezing the rivers in wintertime and affects the water flow in the rivers and poor diversification of the national energy system's generation sources. The maximum capacity of energy production in hydropower plants and other sources in Tajikistan needed during the autumn and wintertime, to cover the energy deficits especially in rural area. There is a high demand for electricity in the Republic with an average of 4.3 TWh. Limitation generally affects all the sectors, cities and rural areas, except the two big cities (Dushanbe and Khujand). Roughly 26,000 residents in the republic are still living in areas that are not electrified (Schulz et al. 2014). As I mentioned above, Tajikistan is mountains country and many villages are in high elevation. The specific nature of the landscape causes some infrastructural problems. Some villages are cut off from electricity access and even water, particularly in the Pamir region. This situation strongly effects to the Tajikistan's economy and lives in rural area. Based on calculations 1 of the 7 people have limited access electricity or none (Stinia et al. 2019). Main source of energy in rural area for heating and cooking especially in winter is wood, biomass and coal, due to lack of other source of energy. Air pollution caused by burning low-quality wood and coal to heat homes or cook meals introduces an immediate threat to residents' lives and health.

Agriculture sector in Tajikistan has strong connection to energy sector, because almost all the arable land in Tajikistan is irrigate by machines. Agriculture in Tajikistan is dependent on irrigation due to differences in climate conditions, which is extremely energy-intensive in some regions as a result of mechanical irrigation pumps. Agriculture is the third largest energy consumer in Tajikistan (Xenarios et al. 2019).

Table 5. Pump irrigation area (in hectares) by height of water lifting in 2015

Location	Pump irrigation area by height of water pumping, ha					Total, ha
	up to 100m	100 - 150m	150 - 200m	200 – 250m	250 - 300m	
Sugd	109.051	24.415	26.040	1.627	1.627	162.760
Khatlon	90.562	11.320	1.029	-	-	102.911
RRS	7.995	2.112	3.922	754	302	15.085
Badakhshon	92	-	-	-	-	92
National	207.700	37.847	30.991	2.381	1.929	280.850

Source (Xenarios et al. 2019)

Nowadays situation and improvement level of the energy does not correspond to the electricity needs inside Tajikistan. Improving the energy consumption in the industrial and housing and public sector on the only hand and insufficient improvement of the sources of energy deliver on the alternative. To deal with this problem it will be crucial to introduce new source of energy technologies and expand using renewable energy sources. Renewable sources of energy such as solar, wind and biomass can effectively cover energy shortage in Tajikistan. Based on reports and researchers Tajikistan has good potential of using renewable source of energy. Based to this estimation, the potential of renewable energy resources such as hydropower, solar radiation, biomass energy, wind energy, and geothermal energy amounts to 527 billion kWh/year, 25 billion kWh/year (calculated values), 2 billion kWh/year, 25–150 billion kWh/year (calculated values), and 45 billion kWh/year (calculated values), respectively. Although if Tajikistan use them in limited extent it will have a positive effect on the energy balance of the country and improve the environmental situation in rural area (Kabutov 2007).

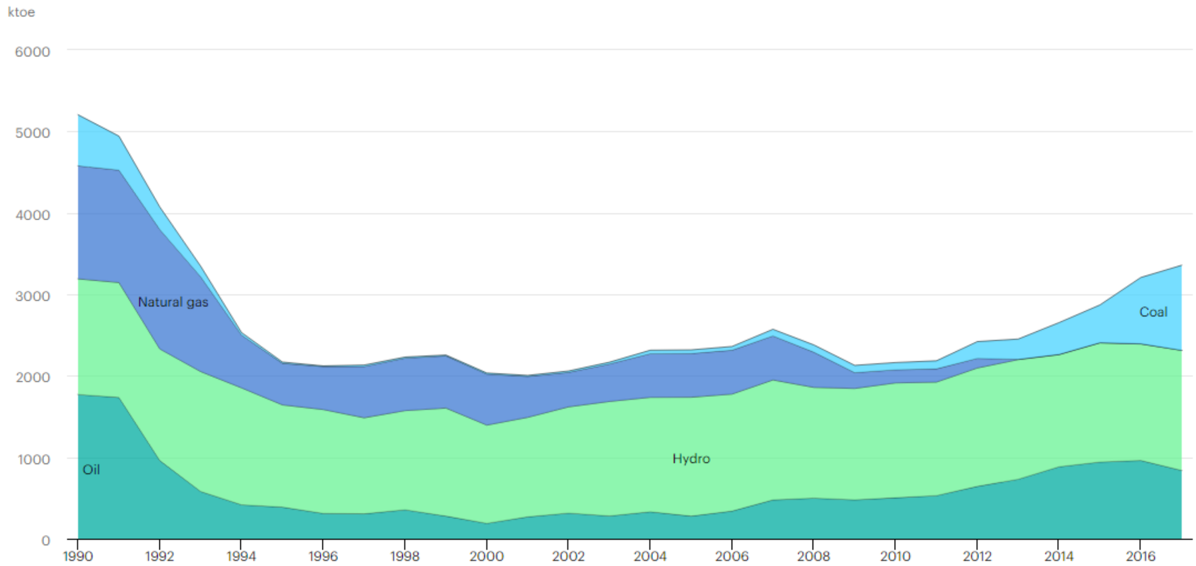

Figure 5. Total primary energy supply in Tajikistan

Source: (International Energy Agency 2020)

Wind energy capability isn't calmly distributed at the territory of Tajikistan. The common annual wind speed at the elevation of 10 m above the surface is 4.1 – 4.8 m/sec and is determined most effective within the mountains and on mountain passes. The common annual wind velocity in different major areas is decreasing: 2.0-3.7 m/sec. Wind energy capacity may be expected primarily based on its availability in inhabitable regions, which represent 7 % of the whole territory of Tajikistan. (Saidov et al. 2016)(Energy Charter Secretariat 2013).

Tajikistan has an exciting potential of using the solar panels. Tajikistan in a territory so called world solar belt. The sunny day per year between 270-300 duration of sunshine 2,100-3,166 per year (Doukas et al. 2012). At the main time solar energy may be important for enhancing the high-quality of lifestyles of the rural population and other hand solar energy technology is one expensive source of energy and will be hard to afford it in rural area.

As I mentioned earlier Tajikistan is agrarian country, using biomass such as (wood, sawdust, household waste, agricultural waste, charcoal, dry manure, grass hay and cotton stalks) renewable source of energy would be one of the best solutions to cover the energy shortages in rural area. Republic of Tajikistan also introduced the National Development Program in 2016 for the period up to 2030. One of the first goal is energy security and efficient use of electricity and to increase energy production from Renewable Energy Sources (RES) up to 20 % against the baseline (Zuhurov et al. 2016). The share of RES in 2012, within the total energy production in Tajikistan was about 0.01 % (Olimbekov 2013). For this purpose, the use of biofuel and biomass in rural areas for heating, cooking and electrical energy is considered not only economically effective, but also necessary. If Tajikistan start to use biomass residues and bioenergy plants at the large livestock farms and poultry farms, it would be not only additional energy but also will contribute to the improvement the living standard of the population and will be a good solution for waste management (Shvedov et al. 2018).

2.3 Agriculture in Tajikistan

Agriculture is one of the main sectors of economy and source of income for population. Thanks to agriculture sector helped to Tajikistan's economy and population especially in rural area during the civil war (1992 - 1997) (Kurbonov & Pulatova 2011). Because of the mountainous terrain of the country, agricultural land, especially arable land, is scarce. Only 35 percent (4,855 million hectares) of the total land area of 14 million hectares are classified as agricultural land. Around 20 percent of this agricultural land is arable (980,000 hectares), with the remaining 3,875 million hectares as pasture (Broka et al. 2016). Approximately 80% of agricultural productivity accounts for crop production. Throughout arable fields, maize and cotton predominate, cotton becoming the main agricultural product for export. The production of fruit and vegetables for both domestic and export markets is growing.

Irrigation is main part of the agriculture; rainfall is low in Tajikistan. Nearly 70% of the arable land in country is irrigated by machines (700,000 hectares) and most Tajikistan's crop production is produced in irrigated land. Furrow type of irrigation system in use in Tajikistan, almost all the irrigation system is very old and insufficient and much of the physical irrigation infrastructure are in poor condition.

Figure 6. Map of the precipitation Republic of Tajikistan

Source (Muminjonov 2008)

Tajikistan has four main agro – ecological zones, of these three excluding the mountain zone are important for crop and livestock production. These zones are characterized by different production system due to their different geography climate and natural resources (Safarov 2003).

Table 6. Characteristics of agro – ecological zones of Tajikistan

Zone	*Location*	*Precipitation (millimeters)*	*Agricultural land use*
Southern river valley	Khatlon, RRS	150 – 250	Cotton, wheat, rice, vegetables, alfalfa, grapes, citrus, livestock
Northern river valley	Sughd	150 – 250	Cotton, wheat, rice, vegetables, alfalfa, grapes, stone fruit, livestock

Foothill areas	Khatlon, Sughd, RRS	200 – 650	Cereals, potatoes, alfalfa, livestock
Mountain areas	GBAO, Sughd, RRS	>200	Livestock, limited cereal production in valley areas

Source (Lerman & Sedik 2008a; Muminjonov 2008)

Note: RRS – Region of Republican subordination, GBAO – Gorno Badakhshan

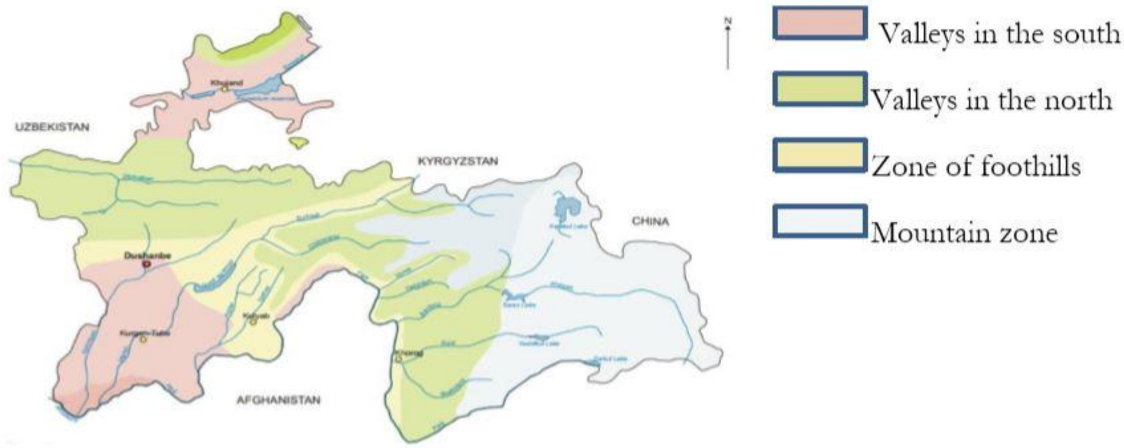

Figure 7. Agro – ecological zones of Tajikistan.

Source (Broka et al. 2016)

According to the (FAO 2018) 73 % of population of the country are living in rural areas and majority of the population in rural area involved to the agriculture. Agriculture is one of the big employment sector, 53 % of the population works in this sector (FAO 2018).

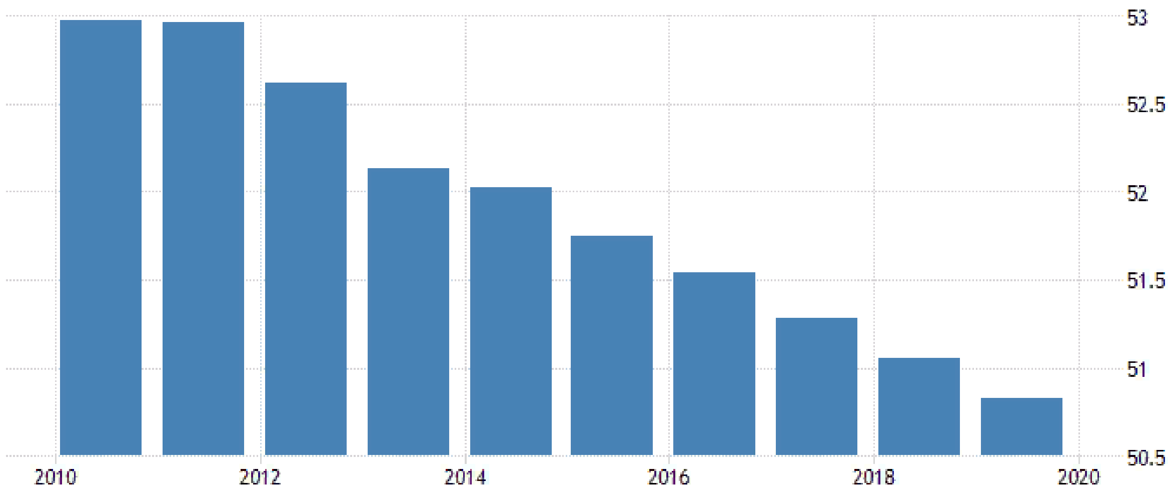

Figure 8. Tajikistan employment in agriculture sector by percentage

Source (Trading Economics 2020)

The agriculture is generating about the quarter of the country's GDP, the main agriculture crops are cotton, maize, cereals, fruits, vegetables, horticulture crops, orchards and others. Primarily the cotton and dry fruits goes to export to different countries such as Russia, Kazakhstan and European countries. President Republic of Tajikistan on his annual speech paid special attention to agro – industrial sector as the main part of the Tajikistan's economy (Ministry of Finance of the Republic of Tajikistan 2009).

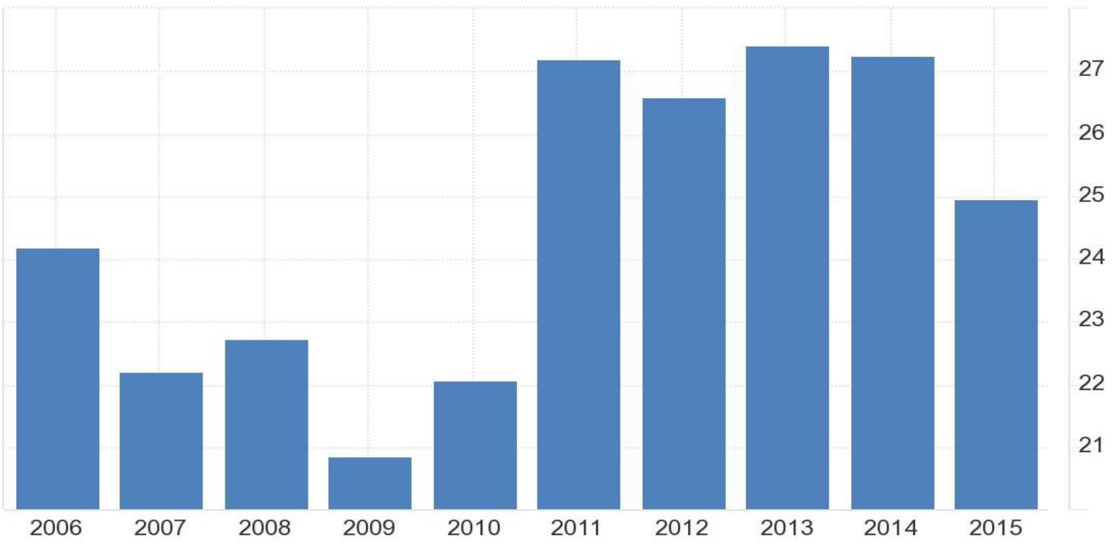

Figure 9. Role of agriculture in Tajikistan's GDP, %

Source ("Tajikistan Agriculture Value Added Percent Of GDP" 2017)

As I mentioned above Tajikistan is mountain country and only 7 % of the territory is suitable for agriculture. Mostly all the arable land is irrigated by pump due to the high elevation. The arable land is about the 5.26 % of the land area in 2014 ("Tajikistan Arable Land Percent of Land Area" 2016). Furthermore, the favorable climate helps to produce several crops, fruits and vegetables. The cotton, fruits and dry fruits are of the main agriculture products which goes to export and help to country's economy.

The end of the Soviet Union and the following civil war had serious consequences for Tajikistan, for agriculture and rural development sectors. And in Tajikistan were remain the *kolkhoz* and *sovkhoz* system of the agriculture. Since the 1997 until nowadays is going on the reforms agriculture system. Tajikistan changed into new corporate forms to reorganize traditional group and state farms into *dekhkan* (peasant) farm in the hope that restructuring would boost productivity in the agriculture sector (Lerman & Sedik 2008b). According to the FAO is now possible to distinguish four types of agricultural producers in Tajikistan. These are:

1. Households plots
2. Individual and family *dekhkan* farms
3. Collective *dekhkan* farm
4. Agriculture enterprises (successors of former state farms)

Today's farming sector consists of about 750,000 rural households, each with an average household plot of 0.3 hectares and almost 90,000 *dekhkan* farms with 7 hectares of arable land or 30 hectares of agricultural land on average. Due to mountainous locations of Tajikistan, weak road connections and market networks it is difficult to transport the agricultural products to larger markets of Khujand and Dushanbe city (Shtaltovna 2013). Majority of small-scale farmers are poor and not able to pay for agricultural advisory serves.

Land reform in Tajikistan has made significant achievements to recovery agricultural production and brought the Tajikistan to the pre - transition by 2007. Agricultural reform was mainly responsible for this aim by increasing the amount of land available to household plots and dehkan farms. Perhaps even more changes happened in agriculture production for family plots and helped to better recovery after civil war and life in rural area (Lerman & Sedik 2009). Land and farm privatization effected positively especially in agricultural production. In 2001 individuals and dekhkan farms already accounted for 61 % of the total production in this sector.

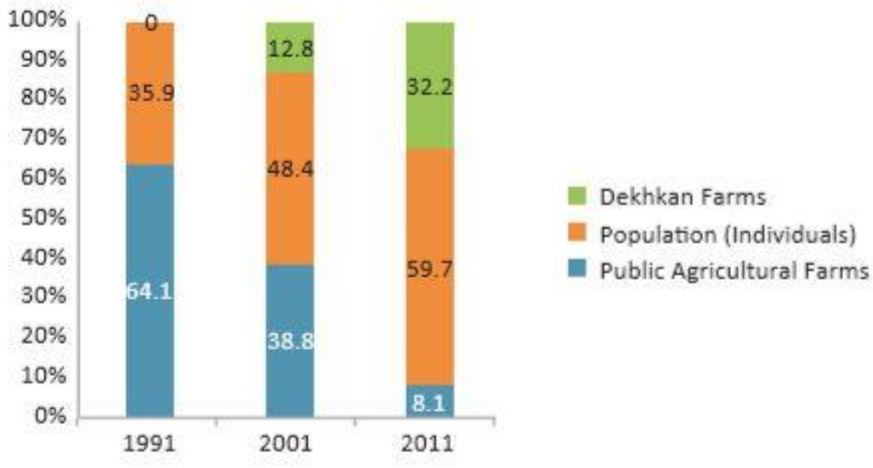

Figure 10. Gross agriculture outputs by type of the producers in Tajikistan by percentage

Source (Asadov 2013)

Recently, cereal production has been increased in Tajikistan by dekhkan farms and individual farms. And wheat production by dekhkan farms were accounted for half of the output in 2011. In the same year for better productivity growth in agriculture the Government of Tajikistan and Ministry of Agriculture signed the memorandum between the People's Republic of China to agreed and corporate and exchange the practical experience in agricultural sector (Asadov 2013). Based on Ministry of agriculture in Republic of Tajikistan, cotton is main farming products and has crucial role in country's economy. Cotton production has been changing up and down through the independency in Tajikistan. Cotton remains the second product for export after aluminum. In 2017 cotton production in Tajikistan was 570.000 tons (IndexMundi 2019a). After land reform in 2012 the production of cotton has been decreased but in last couple year is changing, it's starting to increase. A large proportion of cotton exports makes the Tajikistan in top 20 cotton producers in the world. On the other hand, Tajikistan's economy is dependent on world cotton price. At the moment Tajikistan is exporting the raw material (cotton) to other countries. According to Government of Tajikistan and development plan by 2030 changing from agrarian country to industry-agrarian country, which is producing more cotton but processing inside the country and export as ready product.

Another main agriculture product in Tajikistan is wheat, which is main source of food to the population. Like other countries in Central Asia, Tajikistan is bread consuming country and wheat production is considered to be one of the main agriculture products. The current historical and socio-political changes, however, have significantly affected wheat and cereal production in general. After independency achieving the food safety and food security was major plan for the government of Tajikistan, especially in wheat production. According the Ministry of Agriculture the total demand of the wheat per year is 1.5 – 2 million tons. At the same time was paid close attention to wheat cultivation, because it provides about 60% of the food requirements of the country. To increase the grain production was developed and adopted the program by the government of Tajikistan and many new varieties of wheat have been developed by scientist in Tajik Agrarian University and Tajik Agricultural Academy of Scientist. Even though wheat production is still not enough to cover the local consumption, but it's also imports from other countries (Sultanova 2012). In the following graph (Figure 11) is presented the wheat production in Tajikistan.

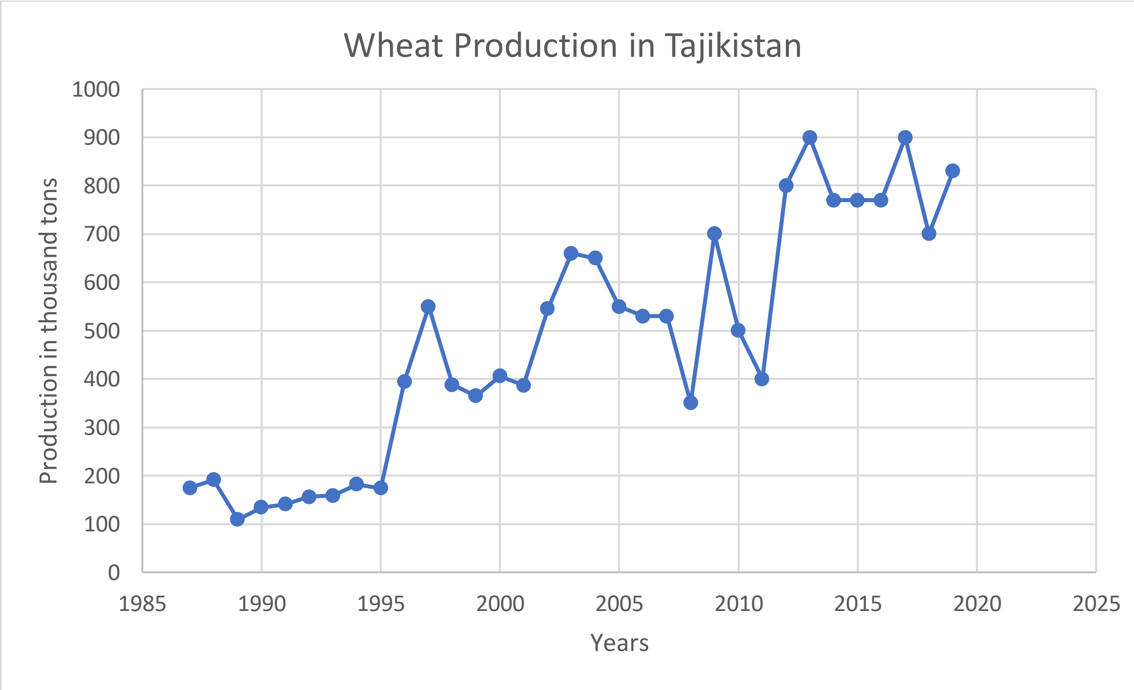

Figure 11. Wheat production in Tajikistan from 1987 - 2019

Source (IndexMundi 2019b)

Horticulture and gardening are another important agriculture sector in Tajikistan, because more than 50% of population in works in agriculture sector. Gardening has big role and almost the main source of income for rural population. Tajikistan has the best climate condition to create a garden and produce more fruits such as grapes, apricot, peaches, pears and plums (Kamolov 2012). In 2016 under gardens 180.000 hectares of land was occupied. Mainly gardens and orchards are located in Sogd, Khatlon and district of Republican subordination

(Ansor 2019). Annually Tajikistan produce around 1 million tons of fruits and approximately 20 % of it goes to export to other countries such as Russia, Kazakhstan, China and others. Due to importance the role of gardening, orchards and fruit production in socio – economic sector of Tajikistan, in 2015 the Government of Republic of Tajikistan paid special attention and made new development plan for 2016 – 2020 years to create the gardens and orchards (The government of the Republic of Tajikistan 2015). Tajik Statistical agency reported 132.628 tons of apricot has been produced in 2017. Overall Tajikistan is agrarian country and agriculture has a great influence on country's economy and population especially in rural area.

2.3.1 Cotton

Cotton (Gossypium) is one of the world major cultivated non-food crops. The stem length of cotton stalks ranged from 98 to 182 cm, stem diameter ranged from 7.3 to 15 mm, weight of one stalk ranged from 35 to 200 g and number of branches ranged from 6 to 27 (Eissa et al. 2013) Global cotton demand has risen by an average of 2 percent annually since 1940. Developing countries accounted for 77 % of the world's cotton demand between 1981 and 1998, and their share is growing (Kasimov 2013). Cotton is the most widely used natural fiber in the textile, clothing and other industry. Cotton production are mainly spread around the globe in dry areas. Main cotton lint producers in the worlds are: China, India, USA, Turkey and other, also Tajikistan is in the top 20 cotton producers' countries (Esteve-Turrillas & de la Guardia 2017). Thus, the global cotton production has continuously increased up to current estimates of about 25,000,000 t (Hamawand et al. 2016b; Egbuta et al. 2017).

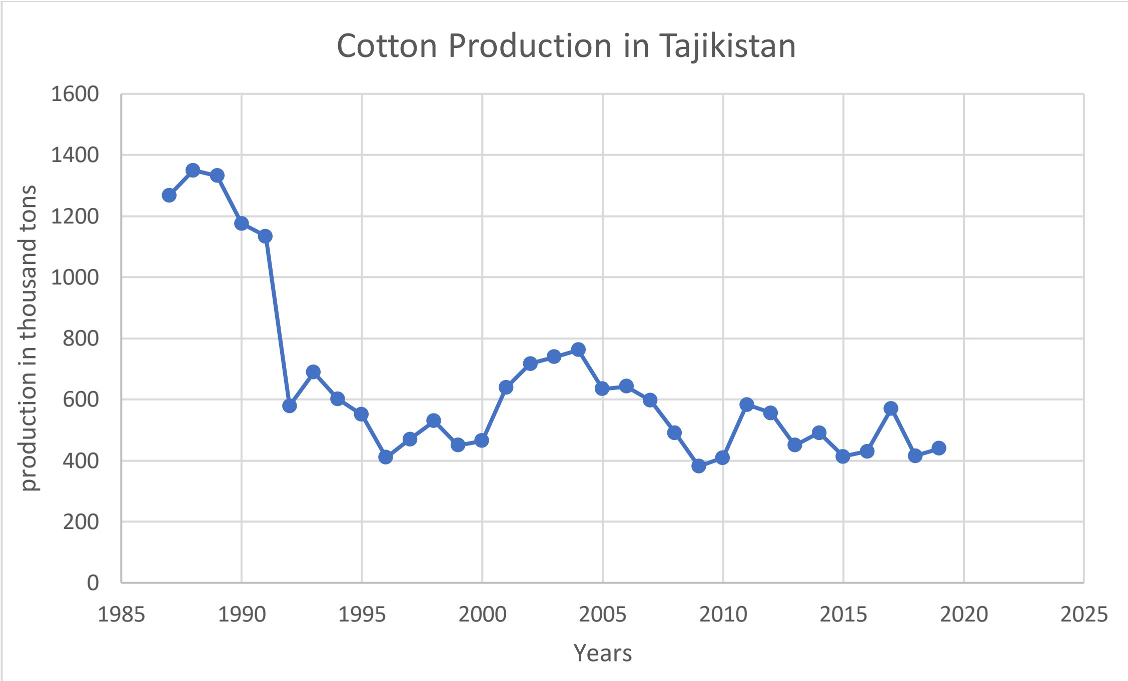

Figure 12. Cotton production in Tajikistan from 1987 – 2019 years

Source (IndexMundi 2019a)

For Tajikistan cotton is an important dominant of an agricultural sector and the primary crop for its economy; with one-third of the total arable area, 75–90 % of agricultural exports and massive portion of country's GDP and main source of income people in rural area. Growth of the value of cotton production is the key factor in reducing rural poverty. Because of the importance of cotton for the economy, the government is very reluctant to relinquish its control over the sector. (World Bank 2012; Kasimov 2013). According to (TAJSTAT 2017) about 370,000 t of cotton was produced in 2015. Agricultural sector employs two-thirds of the Tajik population and cotton industry is the largest employer, which supports 75% of rural population (Boboyorov 2012; Kasimov 2013). Trends in the value of cotton output therefore have 1847 a major impact on overall sectors' growth and people well-being.

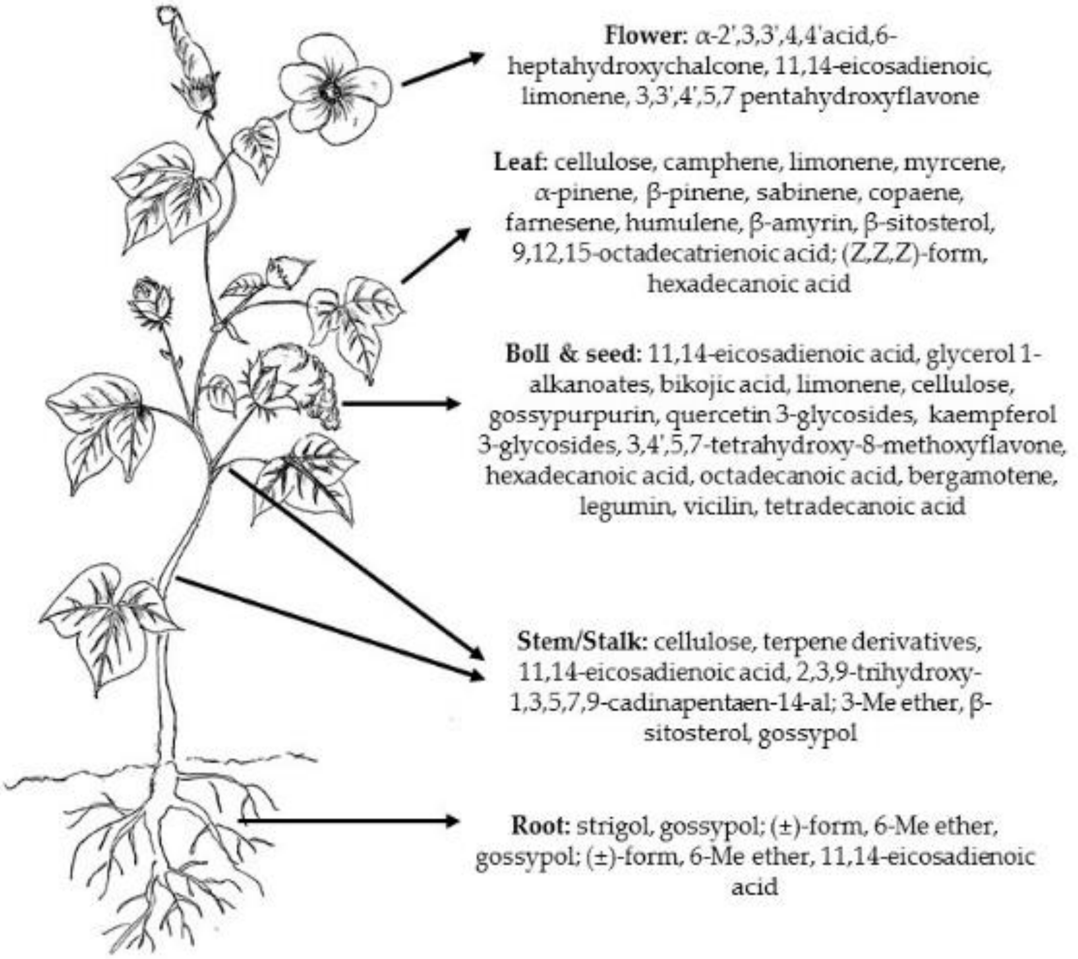

Figure 13. Cotton plant

Source (Egbuta et al. 2017)

Agriculture, cotton production has made a powerful contribution to country's post-war economic recovery. However, Tajikistan remains deeply poor (World Bank 2012) and almost three-quarters of the extreme poor live in cotton growing areas (Boboyorov 2012). According to (Kasimov 2013)'cotton has the potential to be is venue for rural poverty reduction', but the current production, processing and marketing techniques being applied in Tajikistan do not develop the potential gains to be beneficial for local farmers. By Ministry of Agriculture important task of a present state policy program for 2012–2020 is dedicated to improving cotton sector management. Resource-poor farming households all over the Tajikistan have a great level of self-sufficiency in food, fodder and fuel (Ruppen et al. 2016). In the mountain regions in Tajikistan is high demand of energy is considered to be one of the main reasons for natural degradation. Current energy situation, i.e. irregular supply of electricity and the lack of coal, which is also often expensive and of inferior quality, forces reliance on scarce locally available resources (Mislimshoeva et al. 2014)

Moreover, Tajikistan is characterized by harsh winters (World Bank 2012; Mislimshoeva et al. 2014) and long heating period, which lasts from November to March or April (Ruppen et al. 2016). In many villages animal dung and firewood from fruit trees and cultivated vines are the main sources of energy for cooking and heating (Mislimshoeva et al. 2014; Ruppen et al. 2016). Worldwide utilization of crop residues other than cotton for energy purposes has been an interesting subject for years and has got attention of scientists around the world. Agricultural production is growing in the world at the same time is growing the agricultural remnants. Those raw materials can be used to energy purpose through different technologies. A non-fodder agricultural wastes can be utilized as renewable energy in form of briquettes and pellets. Briquetting is one of the compressing technologies through which density of the biomass can be increased and the size can be reduced by 8 – 10 times (Mythili & Venkatachalam 2013; Hamawand et al. 2016b; Egbuta et al. 2017). Recently, the energy potential of cotton waste started to draw researcher's attention, especially in developing countries. The cotton plants itself is a big source of biomass waste which is stays in the field after collecting the cotton. (Hamawand et al. 2016b). Cotton cultivation results in tons of waste (Hamawand et al. 2016b; Egbuta et al. 2017) and faces the producing countries to serious environmental issues. Agricultural products and by-products other than cotton are being utilized to generate energy and materials that serve as a means of recycling and environmental reduction of organic wastes (Eissa et al. 2013; Ranjithkumar et al. 2017).

Cotton waste production was estimated to be 2.9–3.8 times larger than cotton production (Coates 2000; Mythili & Venkatachalam 2013). There are three types of wastes generated during growing and processing: post-harvest field trash (PHT), cotton gin trash (CGT) and seed meal after oil extraction (Egbuta et al. 2017); where PHT represents the biggest source of waste biomass (Hamawand et al. 2016b) According to calculations about 5.2–5.6 t ha-1 of cotton waste is left in the field after harvesting and many growers usually burn it or slash and leave on the field (Egbuta et al. 2017).

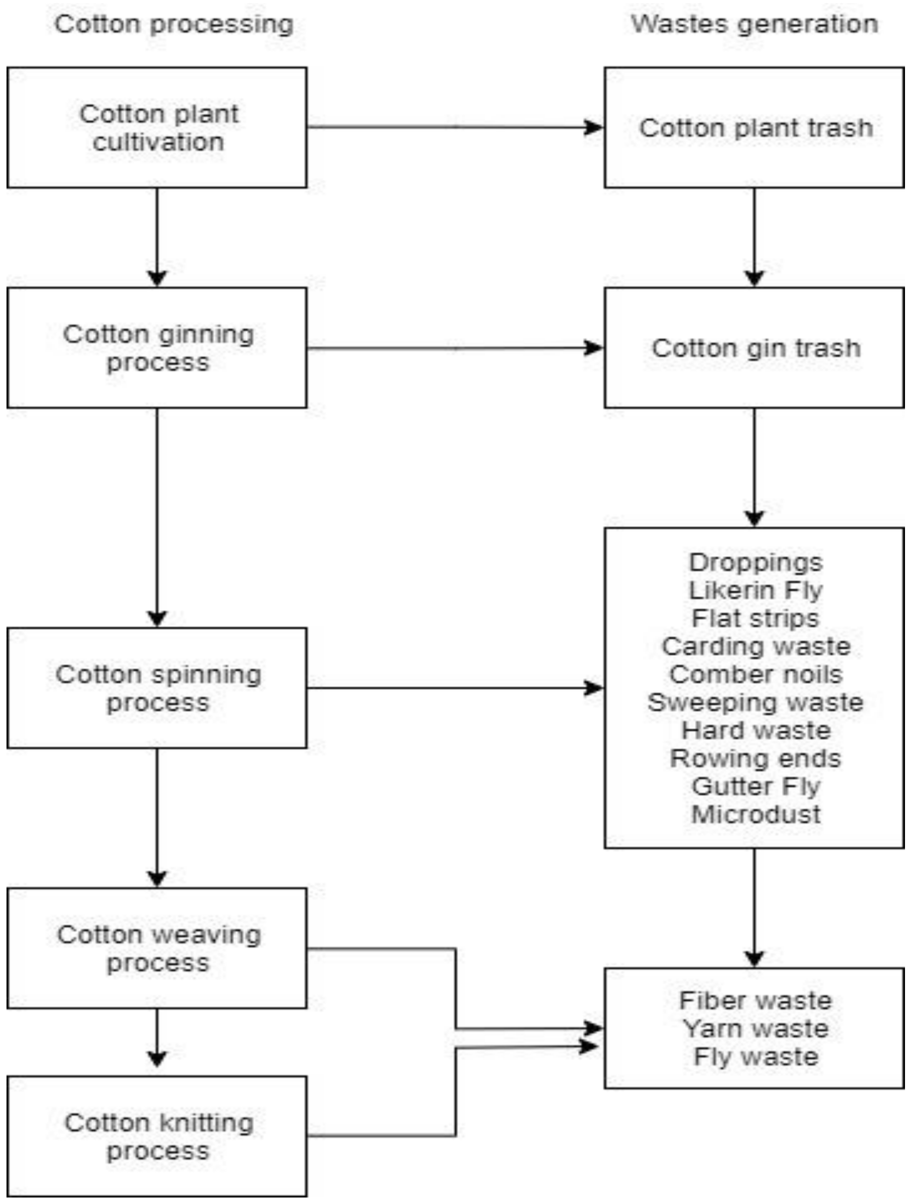

Figure 14. Scheme of the cotton plant treatment

Source (Ranjithkumar et al. 2017)

However, PHT has little value as a soil amendment and tillage operations have high energy requirements and often degrade soil structure (Coates 2000; Hamawand et al. 2016a). Moreover, (Li & Zhang 2016)observed allelopathic effects of naturally decomposed cotton stalks that caused autotoxicity, and much lower and unstable crop production in China. In contrast, (Hamawand et al. 2016a) published that PHT is important for minimizing losses in soil carbon; it provides surface protection and has positive impacts on soil quality.

Therefore, answering the question of how much PHT should be retained in the field and how much should be utilized for other purposes (Sahoo et al. 2016) proved that 80 % of PHT can be removed from most of the cotton land keeping the sustainability indicators within the limit. Additionally, by (Hamawand et al. 2016a) use of PHT as livestock feed is not suitable due to Endosulfan contamination and very poor feeding value. For these reasons, PHT is considered as a negative value biomass (Coates 2000), but it seems to be a good source of bioenergy (Hamawand et al. 2016a). PHT can be processed to all kinds of biofuels: liquid, gaseous and solid, nevertheless, there are still little studies about it. According to (Keshav et al. 2016) PHT is a promising feedstock 1848 for ethanol production due to high holocellulose content, but it is practically applicable only if technical issues associated with this process (especially pre-treatment) are solved (Hamawand et al. 2016a; Ranjithkumar et al. 2017).

Quality bio-oil can be produced from PHT by pyrolysis (Zheng et al. 2008; Hamawand et al. 2016a); however, several barriers need to be overcome such as reducing the amount of char and energy required. By (Isci & Demirer 2007) PHT is a good source of biogas, per contra by (Hamawand et al. 2016a) the biogas production and conversion is low, and it seems to be non-feasible due to the little revenue generated. Several researches were focused on solid biofuels production: (Chen et al. 2017b) has studied chemical characteristics of cotton stalk briquettes; mechanical properties of briquettes produced by screw press were analyzed by (Eissa et al. 2013); research of (Coates 2000) showed that cotton residues can be incorporated with pecan shells to manufacture commercially acceptable briquettes; (Mythili & Venkatachalam 2013) concluded that PHT briquettes are well suited for the energy generation due to high gas production in gasifier; and (Stavjarska 2016a; Sahoo et al. 2016; Hamawand et al. 2016b) stated that PHT can be feasible used to produce fuel pellets.

Thus, PHT presents available source of energy to cotton growers (Hamawand et al. 2016b), but assumed prohibitive cost associated with harvesting the trash for other uses is considered as a major economic hurdle (Egbuta et al. 2017). However, (Coates 2000; Hamawand et al. 2016a) have stated that the energy required to collect and process PHT into briquettes or pellets is a small percentage of the energy content of the residue itself. And, the complexity, capital and operating costs of such application are lower compering to other options (Hamawand et al. 2016b). Therefore, today solid biofuels' production is the most viable solution of recycling PHT into useful products (Eissa et al. 2013). In addition, utilization of PHT as a bioenergy feedstock can offer new incentives to cotton growers (Sahoo et al. 2016);

briquettes/pellets can be commercialized (Avelar et al. 2016). Still there is a lack of research in the area of cotton PHT utilization as solid biofuel and more studies are needed (Hamawand et al. 2016b). The aim of this research is to determine the properties of both pellets and briquettes produced from cotton field residues originated from Tajikistan and to evaluate their quality through solid biofuels' standards.

2.3.2 Apricot

Currently in Tajikistan problems of rational use of irrigated land and land management becomes important, specifically, in horticulture such as apricot orchards and vineyards. As I mentioned above Tajikistan is mountainous country only 7% of the country is suitable for agriculture. Mostly, all the horticulture and orchards are in foothill, mount hill land valley areas (Ministry of Agriculture). According to (TAJSTAT 2017) in the country 115,423 thousands of hectares of orchards of which 61,617 thousand hectares of apricot orchards.

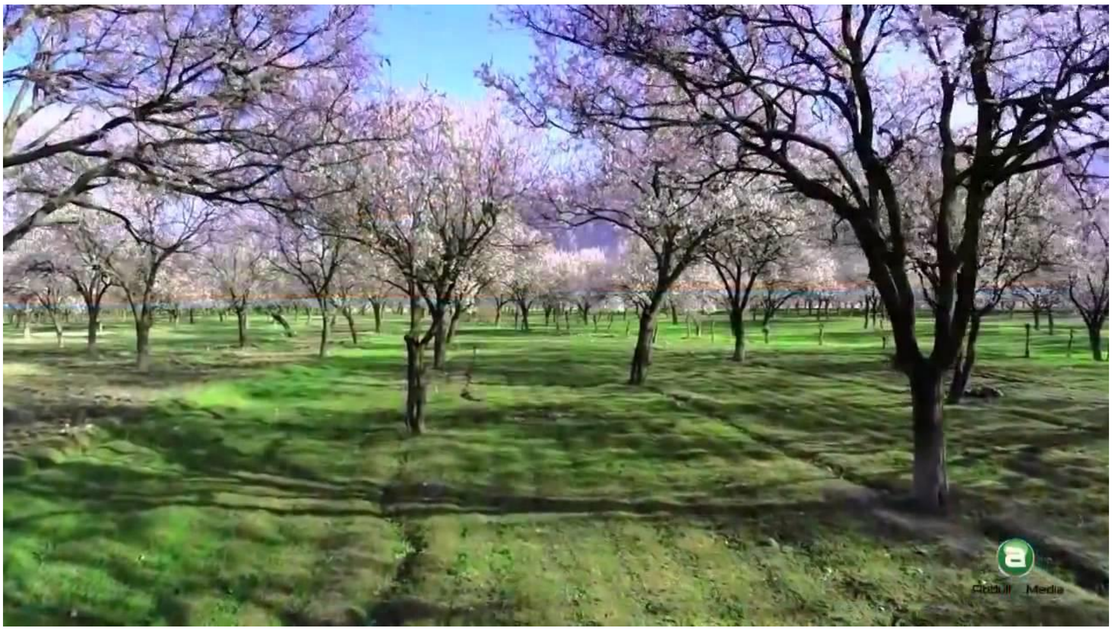

Figure 15. The apricot orchards in Tajikistan

Open source: Ministry of Agriculture, Tajikistan

Among fruit plants, each food producers (agricultural products), and the economic impact, Apricot is one of the leading places. Therefore, the development apricot orchards nowadays have turn out to be a necessity. President's interest to the Republic of Tajikistan Emomali Rahmon to the manufacturing of products and apricot gave impetus to the improvement of this lifestyle. According to the presidential decree of August 27, 2009, from the duration of 2010 to 2014. In the republic must be created 46901 hectares of gardens and vineyards, inclusive of 16714 hectares of apricot (Government of Republic of Tajikistan. Ministry of Agriculture of Tajikistan).

Apricot tree has a peripheral crown and refers to deciduous bushes common height 5-7 m however no longer than 10 m. Apricots develop in special soils: heavy clay, even on gravel and rocky lands. however in mild of heat and fertile sandy soils are nicely bear fruit, and fruits are tastier (Kamolov et al. 2010).

Pruning and forming the fruit plants including apricot - is the main agro-technical treatment, which can be done continuously to adjust growth and development, improve productiveness and fruit high-quality (Demirtas et al. 2010). Most of the fruiting bodies are on the 2-5 years old branches 7-8-year old branches plants dry up and fall off, if left, then very little. Most of the crop is tied at 3-4-year-old branches in young orchards (4-6 years). As a result, proper trimming improves boom and development, is shaped on the proposed tree crown form (Walser et al. 1994).

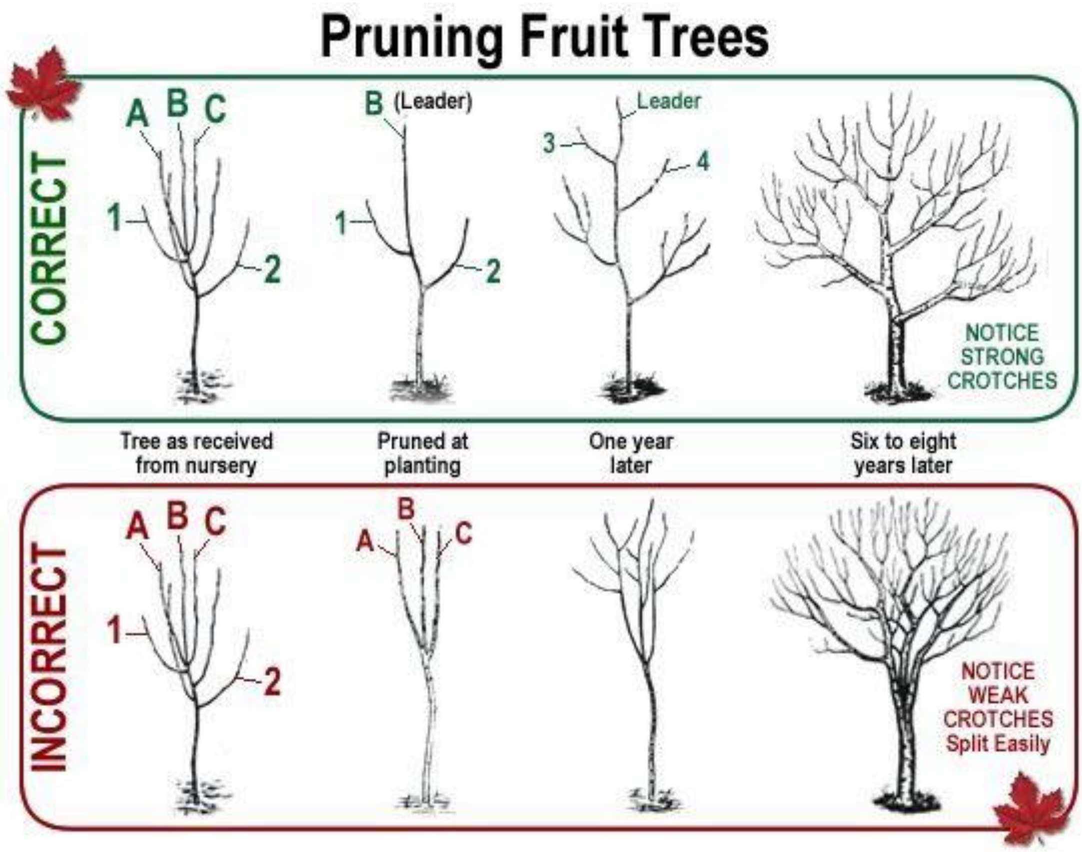

Figure 16. Pruning fruit trees

Source: (Marini 2003)

According to Institute of Gardening and horticulture in Tajikistan the most schematic growing of apricot orchards in Tajikistan is 8x8 (depend on sort of apricot) in one hectare approximately 156 trees. Every year after pruning the one tree approximately 15-20 kg branches available for using as biomass.

3 Hypotheses and objectives

The thesis work was performed under some conceptual conditions, based on the experience and observations acquired during the past studies, and sets out the stated goals of the present thesis. Thus, it includes the main goal and several specific goals thta were specified to accomplish the main objective.

Hypothesis 1

Energy potential/energy yield of residual biomass from apricot tree branches is smaller than energy potential of cotton bushes (in Tajikistan).

Hypothesis 2

Overall quality of solid biofuels made of selected biomass materials fulfills the standard requirements (BS EN ISO 17225 - 1 2014).

Hypothesis 3

Household income influence the intention to use biofuels in form of briquettes and pellets in the future.

Hypothesis 4

Scarcity of energy influence the intention to use biofuels in form of briquettes and pellets in the future.

3.1 Main objective

The main objective of the presented thesis is investigating the agricultural raw material (biomass): cotton bushes and apricot tree branches (after pruning) as renewable source of energy (in the form of the briquettes and pellets) in the Republic of Tajikistan, including production of solid biofuels (both briquettes and pellets) and evaluation of their quality. For the achieving the main objective, specific objectives have been set and presented below.

3.2 Specific objectives

The purpose of the specific objectives is to reach the main objectives, and to discover the energy potential of the raw materials cotton bushes and apricot tree branches. The specific objectives are:

- ❖ Review and study the published articles and reports in the field of briquetting/pelleting also related to agricultural raw materials.
- ❖ Determination and calculation of the potential yield of residual materials (cotton bushes and apricot tree branches).
- ❖ Delivering the raw materials from Republic of Tajikistan for further experimental purpose to the Czech University of Life Sciences in Prague.
- ❖ Preparation of the biomass for the experimental testing.
- ❖ Investigating the physical, chemical and mechanical properties of the agricultural raw materials (cotton bushes and apricot tree branches) and comparing them with International Standards and with other materials.
- ❖ Calculate the energy potential based on the yield of the biomass and gross calorific value (GCV) for the Republic of Tajikistan.

4 Materials and methods

4.1 Methodology

Presented chapter is divided in several parts, based on goal of the thesis. First, description of the investigating materials and their origins. Furthermore, theoretical scientific and practical section. Theoretical part consists of reviewing the related scientific articles published in Web of science, Scopus, ScienceDirect and other sources related with utilization of agricultural wastes. Also, reports from international organization (FAO, World Bank, TAJSTAT, IRENA, Ministry of Agriculture) and other sources has been used. Most of the article and reports were in English, Russian and Tajik languages.

Second part of the methodology is experimental section, which is determination of the physical, chemical and mechanical properties of the chosen material and production of the briquettes and pellets were described. Most of the experiments have been done in the Laboratory of Biofuels in the Faculty of Tropical AgriSciences (FTA), production of briquettes and pellets made in Bioenergy Center of Research Institute of Agricultural Engineering and some chemical properties of the biomass was carried out in Faculty of Agrobiology, Food and Natural Resources in the Laboratory of Environmental Chemistry in CZU.

Another part of the methodology is questionnaire. The purpose of the questionnaire is to understand the real energy situation and type of energy use (for heating and cooking) in rural area and urban area in north part of Tajikistan. Target location for questionnaire is north part of the country, Sogd region. Sogd region is second biggest cotton producer in the country after Hatlon region. Sogd is the biggest region for apricot orchards. After collecting the data, will be done statistics analysis.

4.2 Materials

Chosen materials for investigation are cotton bush and apricot tree branches. Cotton is one-time growing products during the year. After harvesting the cotton, tree from cotton leave in the field as waste materials. Apricot tree branches its material which comes from trimming (cutting) the tree. Pruning the apricot trees happens in late winter or early spring as the new leaves and flowers begin to open and pruning is ones or twice a year. The materials which used for our investigation are available on the field and almost free or very low cost also has big volume, which is not convenient to transport. Another reason to choose those materials are cotton production and apricot orchards (fruit production) has major influence on the economy of the Republic of Tajikistan (see chapter agriculture above). Also, population in rural area are depended in agriculture sector mostly production of cotton and fruits.

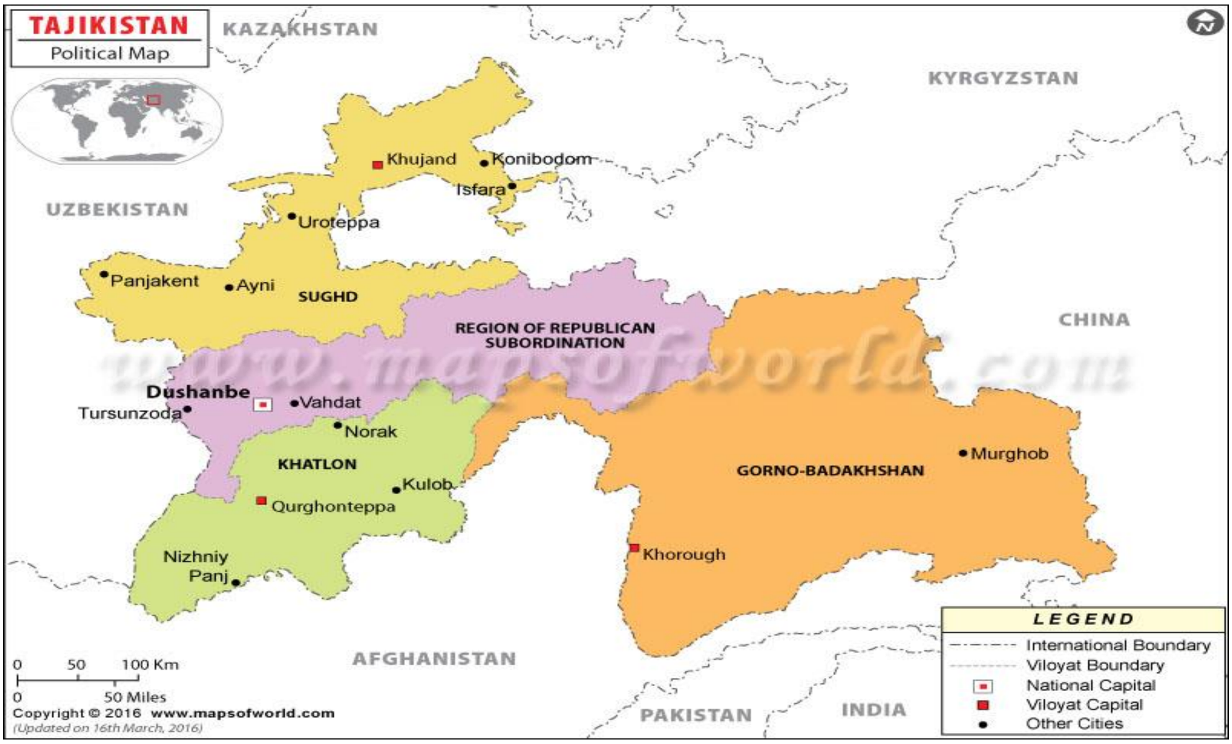

Figure 17. Map of the Republic of Tajikistan

Source: (WorldMaps 2016)

Agricultural waste (cotton bush and apricot tree branch) biomass were brought from the Republic of Tajikistan. Cotton bush was delivered to Czech University of Life Sciences in Prague above 10 kg in December of 2015 from Sogd region, Bobojon Gafurov district from farmland. Cotton bush was harvested manually from three 4x4 meter plots that were randomly selected within one hectare of plantation by the end of November of 2015. Sogd region in Tajikistan is the second biggest region for cotton production also, most of the apricot orchards are located there and climate is suitable for it. Apricot branches (after pruning) was collected manually from ten randomly selected trees within one hectare of orchards and brought in February of 2017 to Czech University of Life Sciences for further investigation, both materials has been collected according the European standard EN 14778:2011 Brief description of the raw materials is presented in chapter agriculture above.

4.3 Preparation of raw materials for briquette and pellet production

For the easier to transport the raw materials, biomass has been cut to smaller pieces. Properly processed immediately after collection; such processing consists of maintaining an appropriate content of moisture and particle size. Biomass samples were collected from Republic of Tajikistan were prepared right after delivering to the Czech University of Life Sciences for experimental testing. Raw materials samples were cut for further experiment and the details about the cutting machines described below.

4.3.1 Material grinding

For diminishing the size of the biomass (cotton bush and apricot tree branch) was used the grinder Bosch, type AXT 25 TC (Stuttgart, Germany). And in order to do smaller piece of biomass another equipment was used, Hammer mill type 9FQ – 40C (Henan, China) and screen size of the machine is 8 – 12 mm and energy input of the equipment is 5.5 kW. Both equipment's are available in the Technical Faculty of Czech University of Life Sciences.

Table 7. Technical specification of grinder Bosch, type AXT 25 TC

Parameters	Units	Value
Cutting system	-	Turbine – Cut System
Motor power	kW	2.5
Cutting capacity, max. diameter	Mm	45
Material throughput, approx..	Kg/h	230
Cutting speed	Rpm	41
Torque, approx.	Nm	650
Weight	Kg	30.5

Source ("AXT 25 TC Quiet shredder | Bosch DIY" 2015)

Figure 18. Bosch, type AXT 25 TC

Source (“AXT 25 TC Quiet shredder | Bosch DIY” 2015)

Figure 19. Hammer mill type 9FQ – 40C

Source (“Qingdao Ruida Machinery Co.,Ltd” 2009)

4.3.2 Briquette and pellet technologies and production process

Biomass is generally abundant and presents an opportunity for renewable energy that could be as an alternative to fossil fuel; however, it is usually considered as waste. Effective utilization of biomass can give many advantages among a renewable and sustainable energy especially in rural area (Obi et al. 2014). Briquetting and pelleting are one method of achieving the renewable and sustainable energy. Briquetting and pelleting of biomass describes technologies for converting crop residues into solid fuel with or without binders in order to improve the handling characteristics of the material for transport, storage and calorific value of the raw material. The purpose of compressing the biomass is making them denser for their use in energy production and briquetting technologies can be divided into (Grover & Mishra 1996):

- ✓ High pressure compaction
- ✓ Medium pressure compaction with a heating device
- ✓ Low pressure compaction with a binder

It is necessary to know the physical and chemical characteristics of biomass, which also affect their behavior as fuel, in order to understand the suitability of biomass for briquetting and pelleting.

Physical properties are of the most important part of the briquetting and pelleting technology, which includes moisture content, bulk density and thermal properties of the biomass. Chemical parameters are another main aspect of the biofuel, which needs to be determined for briquetting and pelleting technologies (Grover & Mishra 1996; Tumuluru et al. 2011; Obi et al. 2014).

For production of the briquettes in our case, high pressure compressing technology has been used. Production of briquettes was processed in Bioenergy Center of Research Institute at Agricultural Engineering in Praha Czech Republic, using the hydraulic briquette press Briklis Brikstar 50. The form of the briquettes is cylinder shape, diameter is 65 mm and length are 30 to 50 mm also heating value is 15 to 18 MJ/kg. The installed capacity of hopper in briquetting press is 0.7 m^3. Detailed characteristics of the briquetting equipment is presented below.

Table 8. Technical specification of Brikstar 50

Parameter	Unit	Value
Output	kg/hour + - 10%	40 – 60
Electric input	kW	5.4
Press weight hopper	M^3	0.7
Permissible moisture of input material	Hm%	8 – 15

Specific weight of the pressed briquette	Kg/m^3	700 – 1,100
Maximum operating pressure	Bar (MPa)	180 (18)
Maximum operating temperature	^{0} C	60
Machine working environment	^{0} C	+5 – +35
Supply voltage	V	400
Control voltage	V	24

Source (Briklis 2015)

The sketch of the Brikstar 50 the briquetting machine is presented below.

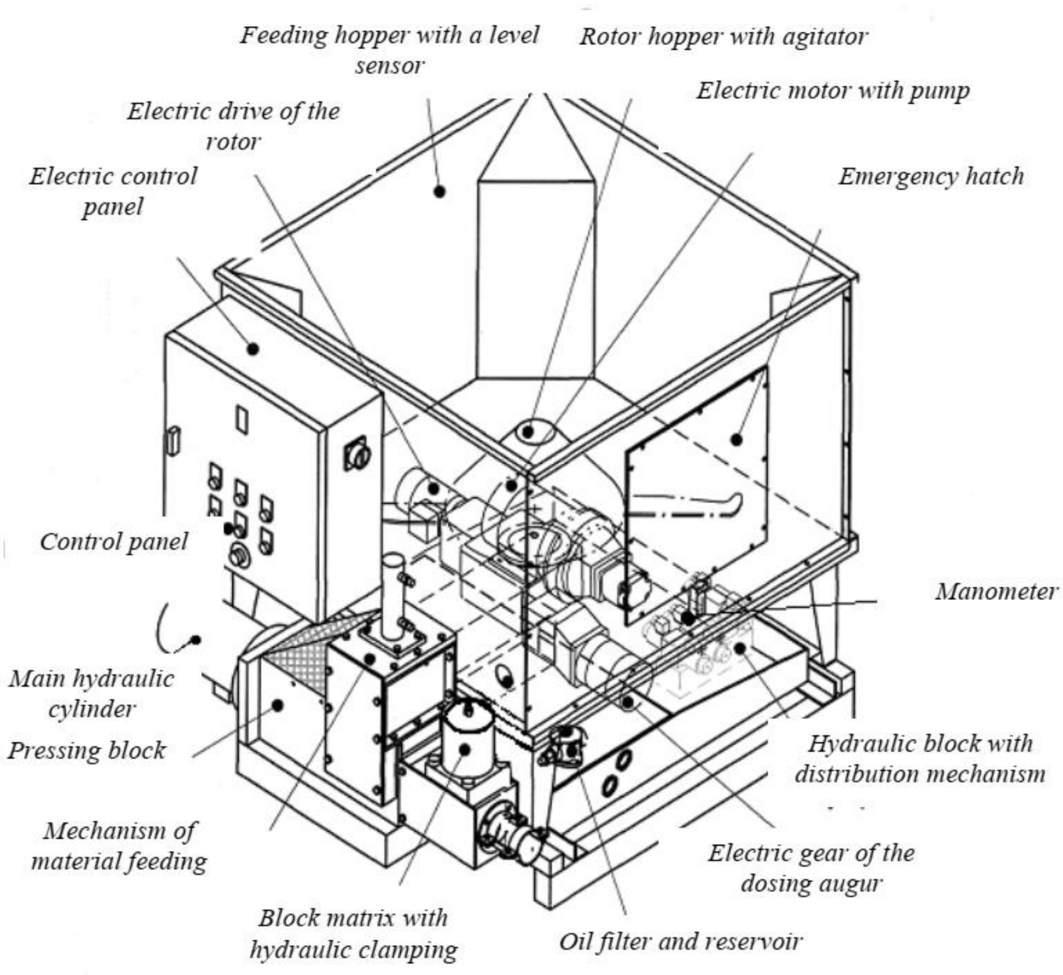

Figure 20. Briquetting machine Brikstar 50

Source (Ivanova 2012)

Pelleting is a way of increasing the bulk density by applying mechanical pressure to the biomass (Döring 2013). Pelletizing method can have many advantages for biomass: reduced amount of dust, increases the energy density, environmental benefits of reduced greenhouse gas emissions and easier control during combustion (Malik et al. 2015). Wood pellets are primarily used in domestic, commercial and industrial heating equipment as energy sources (Lamb et al. 2012; Garcia et al. 2016). Biofuel pellets made from pulverized biomass with or without pressing aids, usually 6 – 25 mm in cylindrical shape, normally 5 to 30 mm in random length, and broken ends. In the small heat sources, there are three basic type of combustion system defined for the biomass pellet (Jevic et al. 2016).

- ✓ Stone hearth stove or small stove (room heater)
- ✓ Hot boilers or automatic hot boilers
- ✓ Special separate burners into various type of boilers

Overall, there are two type of pelletizing system exist, which is flat die and ring die (see Figure 21). In the flat type of pelletizer, die remains stationery and rollers rotate and compress the materials (Döring 2013).

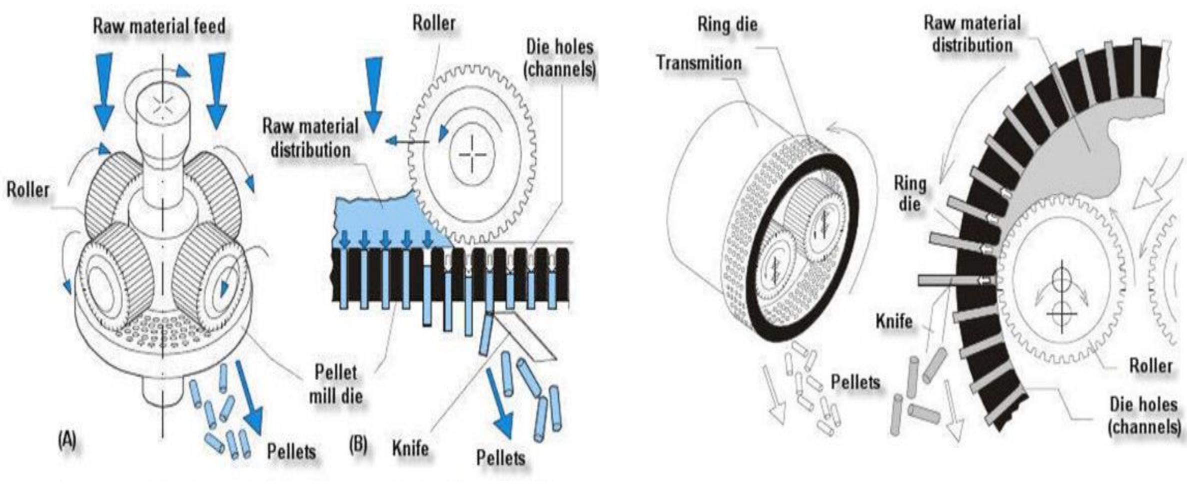

Figure 21. The schemes of two types of pelletizers

Source (Agico Group 2014)

And in the ring die type of system the die itself rotates. In pelletizing process when the biomass passes through the matrix holes, the tension causes the matrix to heat up and the temperature goes up around 75 – 80 ^{0}C. Then, lignin inside the biomass starts flowing off from the fiber; lignin in this condition has ability to bind the fibers (Döring 2013; Malik et al. 2015).

Pellets production for my research carried in Bioenergy Center of Research Institute in Agricultural Engineering and pelletizer machine Kova Novak MGL 200 was used. This pelletizer line is light weight for pelleting the dry biomass from farms and other sources. The main parts of the production lines are bunker with lid equipped with dosing screw, mass mixer which is delivering the materials to the granulating press and, pellets sorting device equipped with cooler. The size of matrix holes is 6 mm, crashed raw materials were put in hopper of pelleting equipment and under the compression through the horizontal matrix pellet were produced. The production capacity of the pelleting machine is up to 300 kg per hour. Electrical consumption of the pelleting line is 8.85 – 10.85 kW/hour.

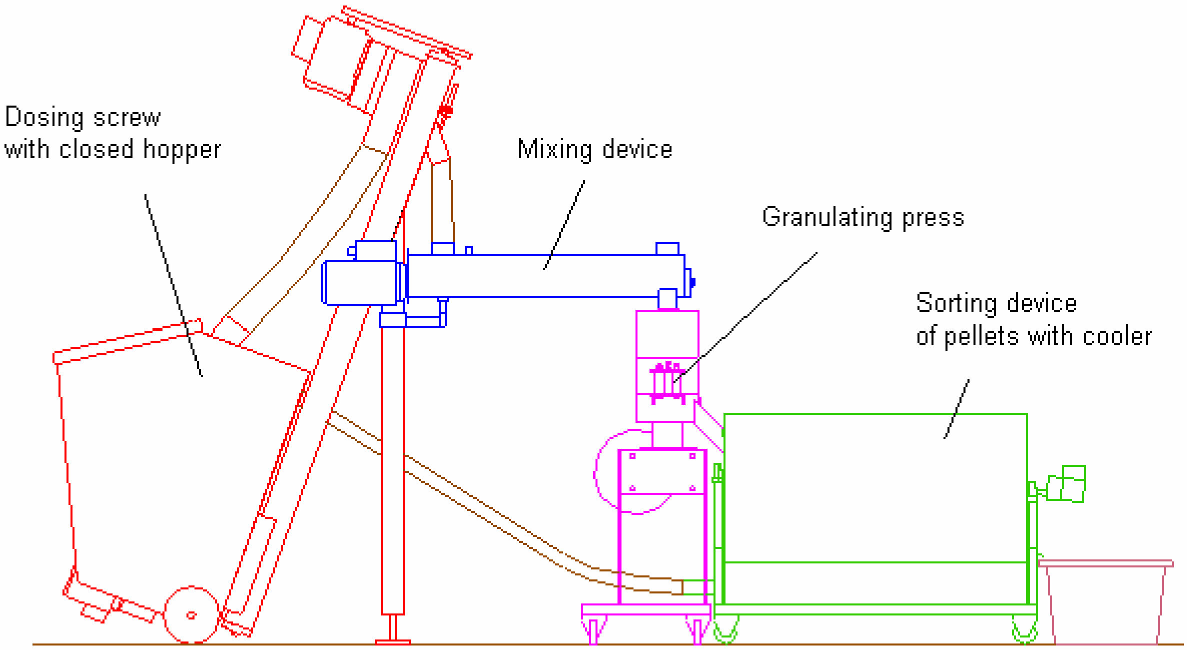

Figure 22. Pelletizer Kova Novak MGL 200

Source (Jevic et al. 2016)

4.4 Preparation of analytical samples

Analytical samples were prepared in the Laboratory of Biofuels in the Faculty of Tropical AgriSciences in Czech University of Life Sciences in Prague. All the samples were made according the (BSI EN 14780 2011) European Standards and ISO standards. Cotton bush and apricot tree branches were cut by scissors to 1-3 cm. And for further grinding the biomass to smaller piece was used the IKA MF 10, due to cut the biomass for less than 1 mm were used knife grinder mill GRINDOMIX GM 1000. Grinded biomass was used for determination of physical and chemical properties. Last step was storing the analytical samples and all samples were kept in glass bowl with a lid in desiccators.

Figure 23. IKA MF10.1

Source (Cole-Parmer Scientific Experts 2012)

Figure 24. Grindomix GM 100

Source (The Lab World Group 2011)

4.5 Experimental measurements and methods

The set of the investigations of the raw materials presented in this thesis, including the physical, chemical and mechanical properties. All the experiments were done according the presented standards (BS EN ISO) with minimum three repetition of each material and the result were examined arithmetic means of nearest measurements, whereas difference between two did not exceed 0.2 % and some parameters even 0.1 %. Experimental measurements were carried out in Laboratory of Biofuels in the Faculty of Tropical AgriSciences, some part of chemical properties of the biomass were done in Laboratory of Environmental Chemistry in Faculty of Agrobiology, Food and Natural Resources in CULS and Biofuels Center at Research Institute of Agricultural Engineering. The whole process of the experiments of each parameter (physical, chemical and mechanical) are presented below.

4.5.1 Moisture content

Moisture content is one of the main parameters of biofuels which effects during the combustion and part of the physical properties. Determination of the water (moisture) content was carried out based on the European Standard (BS EN ISO 18134–3 2015): Solid biofuels – Determination of moisture content – oven dry method. The investigation was done in Laboratory of Biofuels in Faculty of Tropical AgriSciences in CULS. Digital laboratory scale

Kern (model EW 3000 - 2M) with accuracy 0.1 mg was used for weighting the biomass before and after drying. The laboratory oven Memmert model (100 - 800) was used for identification the moisture content of raw materials.

The oven was prepared and heated up to 105 ^{0}C and empty containers also were kept inside the oven. When the constant temperature was achieved in dryer all the empty containers moved out and kept for 15 minutes in desiccators. After the containers were weighted and biomass was placed into containers and weighted again and putted into the oven for 5 hours in 105 ^{0}C. After drying process, the containers were removed from the oven to the desiccator to cool down to the room temperature and weighted one more time. Determination of the moisture content was calculated by the following formula (**1**)

$$w = \frac{m_2 - m_3}{m_2 - m_1} \times 100, \% \quad \textbf{(1)}$$

Where:

w – moisture content (%)

m_1 – mass of empty crucible (g)

m_2 – mass of crucible with sample before drying (g)

m_3 – mass of crucible with sample after drying (g)

The result was calculated as mean of the three measurement (repetition) for each material, difference between of three individual result of each materials was not more than 0.1 %.

Figure 25. Memmert (model 100 - 800) oven laboratory device

Source: (Author 2017)

4.5.2 Ash content

Ash content (inorganic materials) refers one of the important parameters which is stays after combustion in burners/stoves or boilers and creates more problems to burner device, needs more time to clean the ash from stove or boilers. Also, buyers pay attention to ash content parameter of biofuels. Identification of ash content in our research was carried out in Laboratory of biofuels in Faculty of Tropical AgriSciences in Czech University of Life Sciences in Prague. Determination made according the (BS EN ISO 18122 2015): Solid biofuels – Determination of ash content. The calculation of the ash content determined the ash remains after the sample is heated air under controlled condition of the time. Experiment was done in laboratory muffle furnace LAC (model LH 30/13, LAC, Židlochovice, Czech Republic). The maximum heating capacity of the equipment is 1,340 ^{0}C, electricity consumption is 3.2 kW/h and the volume are 30 L.

Analytical samples were crashed to less than 1 mm and dried in oven before putting to the muffle furnace. Further, the empty vessel was kept in muffle furnace for 60 minutes in temperature 550 ^{0}C and after was vessels removed from muffle furnace in left in desiccator for 10 – 15 minutes to cool down. The samples were weighted approximately 1 g and put to vessel then inside the muffle furnace, then temperature in muffle furnace was raised smoothly to 250 ^{0}C for 30 minutes. And biomass was kept in this temperature for 60 minutes due to reduce the volatile materials before burning. The temperature in furnace increased constantly for 30 min until it reached to 550 ^{0}C and kept in this temperature for 120 minutes to achieve the burning.

The containers with ash content was removed from the furnace and kept in desiccators for 10 – 15 minutes in order to cool down to room temperature. After, the samples were weighted and recorded. For the calculation of the ash content was used following formula (**2**)

$$AC = \frac{(m_3 - m_1)}{(m_2 - m_1)} \times 100 \times \frac{100}{100 - w}, \% \qquad (2)$$

Where:

AC – ash content (%)

m_1 – weight of empty crucible (g)

m_2 – weight of crucible with sample (g)

m_3 – weight of crucible with ash (g)

w – water content in a sample expressed as a mass fraction (%)

The result of the measurements of the ash content with three times repetition was calculated and rounded nearest 0.1 %.

Figure 26. Muffle furnace LAC (model LH 30/13)

Source: (Author 2016)

4.5.3 Gross calorific value

The calorific value is the main aspects of the biofuels and measurements of it, is requirements for all biofuels. The heating value is the major importance to the trade of biofuels. The consumers want to get as much as possible energy from the biofuels.

The determination of the calorific value of the presented biomass was carried out in Laboratory of biofuels in Faculty of Tropical AgriSciences in CZU. And identification of calorific value made based on (BS EN 14918 2009): Solid biofuels – Determination of gross calorific value and net calorific value. For determination the gross calorific value was used the laboratory calorimeter MS – 10A LAGET. The samples were dried and weighted before putting to calorimeter bowl and placed into calorimeter vessel. In order to help with burning was used the wire and filled with the oxygen of 28 atmosphere pressure. After the combustion the value of temperature jumps and dTk value is recorded then used for further calculation. The whole process takes around 8 minutes. According the mentioned standards the result of the duplicate determination made in the same laboratory and same equipment shall not exceed by more than 120 J g^{-1}. In presented thesis more than three times of repetition has been made.

The heat from combustion is determined by the exact calculation of the change in calorimeter water temperature and the vessel itself. For calculation of the gross calorific value used the following formula *(GCV)* (**3**)

$$GCV = \frac{dTk \times Tk - (c_1 + c_2)}{m}, \mathrm{J\,g^{-1}} \quad (3)$$

where:

dTk – temperature jump, °C

Tk – heat capacity of calorimeter, (9051) J $°C^{-1}$

c_1 – repair on the heat released by burning spark wire, J

c_2 – repair on the heat of burning paper, J

m – sample weight, g

4.5.4 Net calorific value

Net calorific value (*NCV*) was determined based on the gross heat value (*GCV*). In laboratory testing, the net calorific value is not applicable. Determination of the net calorific value made according the (BS EN 14918 2009): Solid biofuels – Determination of gross calorific value and net calorific value. The water vapor is condensed in the GCV test, but the NCV process water stays in the gas state, i.e. the latent water heat does not cause a condensation the latent water vapor. The net calorific value is calculated by the following formula (**4**)

$$NCV = GCV - 24.42 \times (w + 8.94 \times H), \mathrm{J\,g^{-1}} \quad (4)$$

Where:

NCV – net calorific value (J/g)

GCV – gross calorific value (J/g)

24.42 – coefficient of 1% water in the sample at 25°C (J/g) w – water content in the sample (%)

8.94 – coefficient for the conversion of hydrogen to water

H_a – hydrogen content in the sample (%)

4.5.5 Carbon, Hydrogen and Nitrogen

Biomass's chemical composition is cellulose and hemicelluloses, lignin, extractives, minor and major elements. In the Research Institute of Agriculture Engineering at the Bioenergy center was done the experiments of determination nitrogen, carbon and hydrogen (CNH). Research made according the (BS EN ISO 16948 2015): Determination of total carbon, hydrogen and nitrogen content in solid biofuel. Laboratory device LECO CNH628 were used for determination of CNH content of the biomass. In the aluminum foil were prepared and packed all the samples. Samples were weighted approximately 0.1 g and dried before the experiment then placed into machine. The biomass was inserted to autoloader into purge inner tube due to remove the atmospheric gas. Then the materials were transferred into dual furnace and the temperature of the operating system was up to 1,050 ^{0}C with clean oxygen to ensure all samples were burnt. The results of the experiment were automatically estimated and provided by the computer. Each material has been tested three times.

4.5.6 Heavy metal identification

Determination of the heavy metal was carried out according the (BS EN ISO 16968 2015): Solid biofuels- Determination of minor elements was done the Laboratory of Environmental Chemistry in the Interfaculty Centre of Environmental Sciences, Czech University of Life Sciences in Prague.

Frozen and homogenized samples were decomposed in a microwave-assisted wet digestion system with a focused microwave heating system (Discover SPD-Plus, CEM Inc.). The sample weighed an aliquot (~0.3 g of dry matter, in 3 replicates) in a quartz-glass digestive vessel (volume 35 ml) and 6.0 ml of concentrated nitric acid (Analytika Ltd.); the mixture was heated at a maximum power of 300 W, a temperature of 180 ° C and a maximum pressure of 21 bar for 12 minutes. After cooling, the solution was transferred quantitatively to polyethylene plastic tubes, filled up with MilliQ water to 30 ml, and kept until measurement at laboratory temperature. Digested element contents were measured using inductively coupled plasma mass spectrometry (ICP-MS, Agilent 7700x, Agilent Technologies Inc.) without gas mode or collision cell mode to reduce potential interferences. The result of the experiments was calculated automatically by the equipment and with three repetition of each material.

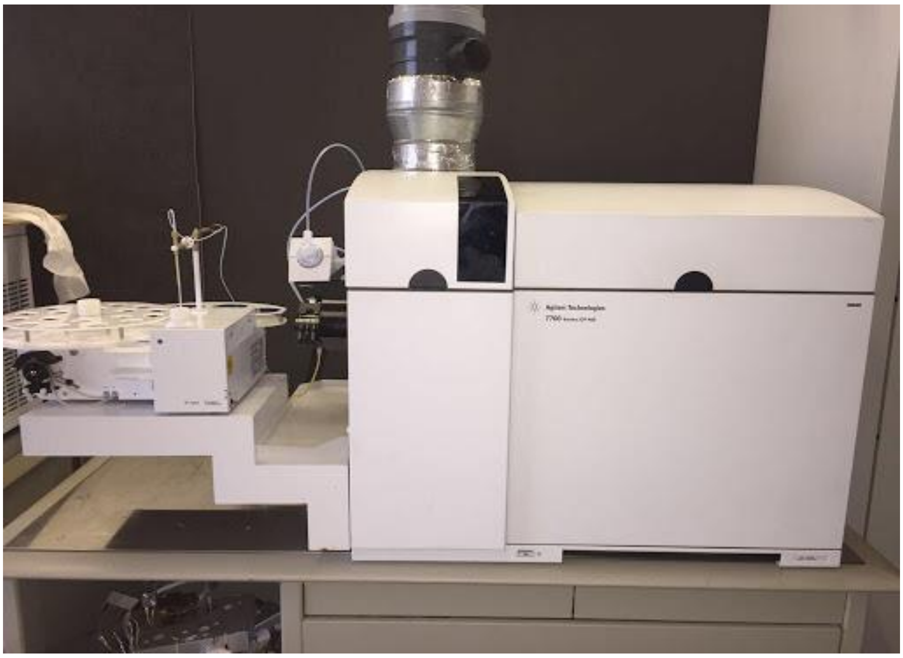

Figure 27. Laboratory equipment Agilent ICP - MS 7700x, Agilent Technologies Inc.

Source (Author 2019)

4.5.7 Volatile matter

Volatile constituents are gaseous compounds that escape when a fuel is heated under specified conditions. They consist largely of fuel gasses and serve to some extent as a measure of the ignitability of the fuels in a combustion plant. Determination of volatile matter of biomass is burning them under specific condition without oxygen such as loss of weight after deducting the weight of moisture content in the raw materials. Whole process of the determination of volatile matter in our research done based on standardization (BS EN ISO 18123 2015): Solid biofuels - Determination of the content of volatile matter.

Experiments was done in the laboratory equipment ELSKLO MF5 in the Research institute of Agriculture Engineering at the Bioenergy center in Ruzyně, CZ. Each of the materials has been examined three times. First the empty vessel with cover were put inside the muffle furnace at the temperature 900 ^{0}C for 7 minutes. After vessels were removed and kept in desiccators for cooling down to the room temperature. Further approximately 1 g of grinded biomass were put to the same vessel and inserted inside the muffle furnace at the temperature 900 ± 10 ^{0}C for 7 minutes. And then removed after 7 minutes and left in desiccators for cool off to the indoor temperature and weighted again data was recorded. For the calculation of volatile matter content of the biomass was used following formula (**5**)

$$VM = \left[\frac{100(m_2 - m_3)}{m_2 - m_1} - M_{ad}\right] \times \left(\frac{100}{100 - M_{ad}}\right), \% \qquad \textbf{(5)}$$

where:

VM – volatile matter

m_1 – mass of empty vessel and lid (g)

m_2 – mass of vessel with sample and lid before heating (g)

m_3 – mass of vessel with sample and lid after heating

M_{ad} – moisture percentage by mass in the general analysis sample (%)

4.5.8 Mechanical durability

Mechanical durability of the biofuels shows the quality of them which effects during the transportation. Mechanical durability of pellets and briquettes was done according the standards (BS EN ISO 17831 - 1 2015) using the pellet tester and mechanical durability of briquettes was done by (BS EN ISO 17831–2 2015) in rotation drum.

At the Bioenergy Center in Research Institute of Agricultural Engineering in Prague, experiment was conducted to determine mechanical toughness of pellets. And the Pellet tester with rotation steel drum and turn speed of 50 per minute was used for the test. The samples of the pellets were prepared and measured at a total mass of 2.5 kg. A large portion of the samples were then divided into four sections and two of them were sieved through the sieve of 40 cm in size and 3.15 mm in holes. Four times 500 ± 10 g of sieved pellets were weighted and placed into a pellet tester for 10 minutes. The pellets were weighted one more time after the experiment ended.

Determination of mechanical durability of briquettes at the Technical Faculty (TF) of the Czech University of Life Sciences (CZU); The steel cylinder-form abrasion with volume 160 liters (depth 598 ± 8 mm, inner diameter 598 ± 8 mm) was used for measuring mechanical toughness of briquettes and the equipment's rotation speed is 21±0.1 per minute. Arm fitted with barrier rectangular steel (length 598±8 mm, height 200±2 mm).

Briquet samples arranged and weighed the required mass of 2 kg (± 0.1 kg) to the rich before determination with four-time repetition. Then samples were added 5 minutes into the machine. The briquettes hit the steel partition inside the running drum which causes the scrape. The formula was used for calculating the result of mechanical durability of the pellets and briquettes (**6**)

$$DU = \frac{m_A}{m_E} \times 100, \% \quad (6)$$

Where:

DU – mechanical durability (%)

m_A – sample weight after crumbling (g)

m_E – sample weight before crumbling (g)

4.6 Calculation of raw biomass (cotton bushes and apricot tree branches after pruning)

Determination of yearly amount of wastes for one hectare calculated with the following formula (**7**)

$$W_{ha} = Q_{Tha} \times Q_{TW}, \text{ t ha}^{-1} \quad (7)$$

Where:

W_{ha} – yearly amount of wastes obtained for one hectare, t;

Q_{Tha} – the number of bushes or trees per one hectare;

Q_{TW} – the quantity of wastes obtained for one bushes or trees, kg;

Determination of the yearly amount of the raw material is calculated by the following formula (**8**)

$$W_T = W_{ha} \times Q_{TT}, \text{ t} \quad (8)$$

Where:

W_T – total amount of wastes obtained (t);

Q_{TT} – total area of cotton and apricot orchards in Tajikistan, hectares (ha);

4.7 Calculation of total energy yield

Calculation was considered for the Republic of Tajikistan. For achieving the maximum theoretical energy yield it is necessary to multiply the NCV in unit MJ kg^{-1} to the total amount of waste obtained in ton (t).

Determination of the total energy yield was calculated by following formula (**9**)

$$E_{YA} = W_T \times NCV, \text{TJ} \quad (\mathbf{9})$$

Where:

W_T – total yearly quantity of cotton bush and apricot waste, t;

NCV – net calorific value of cotton bush and apricot waste biomass, J g^{-1}

4.8 Quantitative Survey

The purpose of the questionnaire evaluating the energy use in rural and urban area in north part of the Tajikistan has a supportive character for our research. The questionnaire was divided into three main parts: demographic characteristics, energy use in rural and urban area and usage of the briquettes and pellets in rural and urban area. Overall, the questionnaire has 25 questions. Target area for the questionnaire was chosen north part of Tajikistan detailed and description of the target area is presented in the following chapter (***see section 4.8.1.***). Further collected data from the questionnaire were statistically analyzed.

4.8.1 Target Area

The first step was the purposive selection of the study area. For the questionnaire survey the target area of the Sughd region Republic of Tajikistan was selected because it involves the second biggest cotton producer, in 2017 according (TAJSTAT 2017) 117.445 tons of cotton has been produced in this region and 79.615 tons of apricot is harvested in addition, raw materials for our research is brought from this area (***see section 4.2.***). The area of the Sughd region is 25,400 km^2 and population of the whole region is 2,654,400 in 2019 (GoT 2019). The capital city of the Sughd region is Khujand city with the population approximately 181,600

(TAJSTAT 2017). The Sughd region is divided into 14 districts and divided into shahrak, jamoat, dehot, and qilshoq. More than 60 % of the population is involved in agriculture sector. The key production areas are the food industry, which is focused on the growth of agriculture (first of all, vegetable and fruit production) and a light industry that is associated with a full cotton processing cycle (Khabibovich et al. 2016)

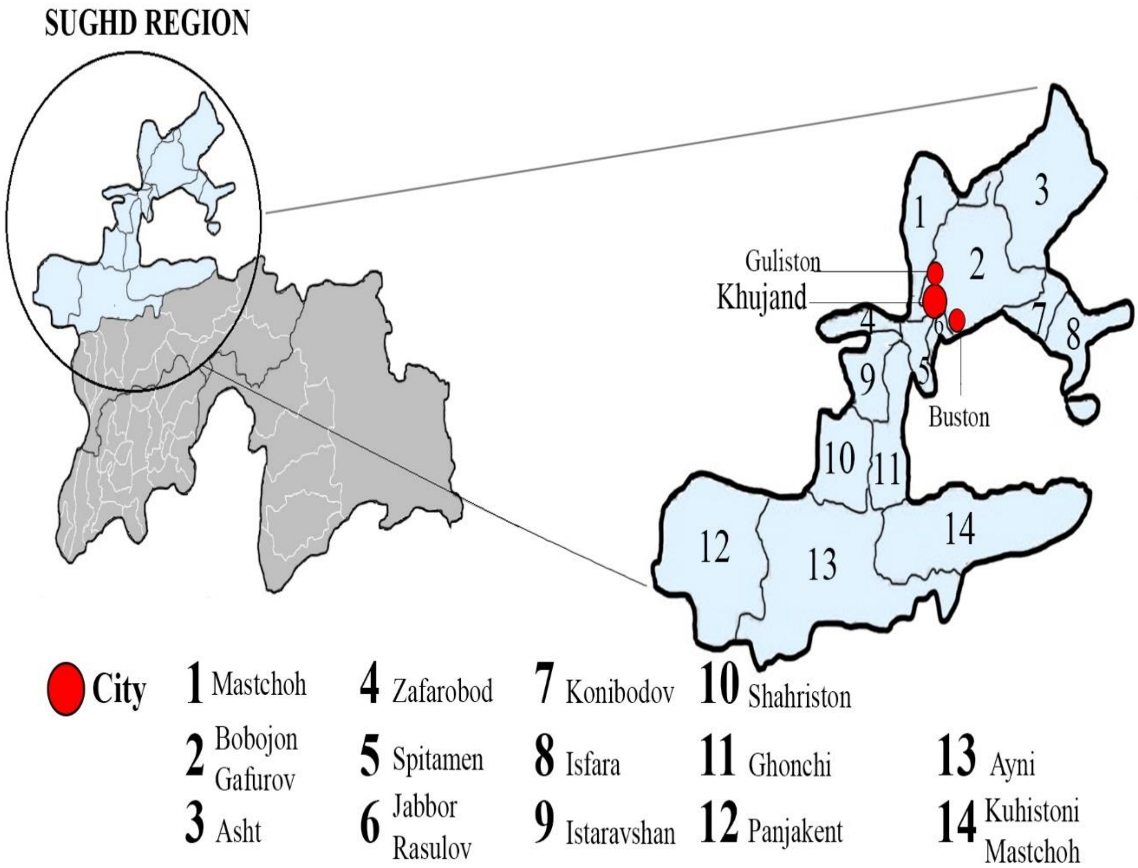

Figure 28. Map of the Sughd region, Republic of Tajikistan

Source (Author 2020)

The main source of economy in all the districts is agriculture. Also, there are few light industries in all the regions which is processing the agriculture products including the cotton, vegetables and fruits. At the same time in some districts there are a heavy industry. But the agriculture is still major sector in economy and life of the population especially in rural area. In Table 9 there are presented details of districts.

Table 9. Districts and cities of Sughd regions

Districts and cities	Area, km^2	Population	Agricultural area, ha	Type of agricultural products	Number of industries (light/heavy)
Khujand city	39.96	174,100	-	-	597
Buston city	29.7	35,540	-	-	26
Guliston city	135.2	47,600	-	-	30
Ash	2,790	162,233	10,978	cotton, wheat, vegetables	12
Ayni	5,200	75,686	3,269	wheat, vegetables	3
Bobojon Gafurov	2,651.7	297,900	23,200	cotton, wheat, fruits	2
Devashtich	1,588.7	169,363	96,240	cotton, wheat, vegetables	11
Isfara	835.9	222,600	4,300	wheat, vegetables, fruits	20
Istaravshan	7.63	260,000	25,800	wheat, vegetables, fruits	21
Jabbor Rasulov	3,214	135,687	14,702	cotton, wheat, vegetables	23
Konibodom	828.9	209,600	9,175	cotton, vegetables, fruits	44
Kuhistoni Mastchoh	3,683.2	24,344	4,435	wheat, vegetables, fruits	2

Mastchoh	4,712.3	124,200	23,335	cotton, wheat, vegetables	30
Panjakent	3,700	230,400	18,700	wheat, vegetables, fruits	13
Shahriston	1,140	31,200	13,200	wheat, vegetables, fruits	2
Spitamen	355.7	118,409	16,425	wheat, vegetables, fruits	10
Zafarobod	441	56,753	25,832	cotton, wheat, vegetables	10

Source (Government of Sughd region 2018)

4.8.2 Data Collection and Target Group

Non - random sampling method was used to collect data. The collection of data conducted in two main levels: regional and districts (rural area). The questionnaire with multiple choices and open type of questions was translated into Tajik language. The questionnaire was divided into three parts:

I. **Demographic part** – gender, age, locality, education level and monthly family income
II. **Energy use** – type of energy, source of energy, heating system, money spending for energy, energy scarcity and quantity of energy per season
III. **Use of biofuels (in form of briquettes and pellets)** – informative information about the biofuels, usage the biofuels, etc.

The full form of the questionnaire in English and Tajik languages is available in (***Annex***). The survey was conducted between December 2019 and February 2020 in rural areas of Sughd region Republic of Tajikistan. Before collecting data, the survey was pilot in Bobojon Gafurov district, Histevarz jamoat. During the pilot test following feedback questions were reflected by the author:

- Are all the words and questions clear?

- ❖ Is the question interpreted equally by all respondents?
- ❖ Do interviewees follow directions correctly?
- ❖ Do questions encourage people to answer?

After the pilot testing a small change were made to collect the right and relevant answers. The questionnaire was supported by the Social department of local Government also, by the staff of the Polytechnical University of Tajikistan branch in Khujand city the Department of Economy and Sociology.

Snowball sampling was used to select the respondents. Respondents were inhabitants involved in agriculture sector and mainly living in rural area of Sughd region. First three (n = 3) respondent were farmers from Histevarz village in Bobojon Gafurov area and involved in cotton production sectors and another five (n = 5) respondent were families involved in apricot production sector. Surveyed respondents suggested other farmers involved in cotton or apricot production in the area. These respondents were met face-to-face (n = 21) or they received link to the survey by e-mails or social media (n = 64). Total number of respondents from the Sughd regions were eighty-five. During the face to face interview majority of times head of the family was interviewed. In the presented thesis, I mainly focused on inhabitants living in Sughd region districts and rural areas also, the areas closer to the urban area. Respondent were 18 years old or older.

4.8.3 Quantitative Data Analysis

Firstly, the collected data was analyzed by descriptive and inferential statistics. The Chi – square test (Pearson 1900) and Fisher exact test (Fisher 1922) was used. Secondly, binary probit model was used to analyze the factors influencing the intention of respondents to use biofuels in form or briquettes and pellets in the future.

The Chi – square test of independence determines whether there is an association between two categorical or binary variables (i. e., whether the variables are independent or related) test was used to analyze, if the education or income of respondents and intention to use of briquettes and pellets in the future is related. Moreover, the association between energy scarcity and intention to use of briquettes and pellets in the future was tested. The used variables are described in the Table 23

Based on (Ana-gabriela 2017), following formula was applied (**10**)

$$X^2 = \sum_{i=1}^{R} \sum_{j=1}^{C} \frac{(o_{ij} - e_{ij})^2}{e_{ij}} \tag{10}$$

Where:

o_{ij} – is the observed cell count in the i^{th} row and j^{th} columns on the table

R – is the number of rows in the contingency table

C – is the number of columns in the contingency table

e_{ij} – is the expected cell count in the i^{th} row and j^{th} column of the table, calculated as (**11**)

$$e_{ij} = \frac{row\ i\ total\ x\ col\ i\ total}{grand\ total} \tag{11}$$

4.8.4 Binary Probit Model

Secondly, the binary probit model also called probit regression where the variable base is a discrete random variable with zero or one values (Horowitz & Savin 2001) was used. Binary output variables are dependent variables with two options, such as yes / no, positive test result / negative test result. Simple binary probit test was proceeded to find out the influencing characteristics on intention to use the briquettes and pellets in the future in north part of Tajikistan. The probit method analysis gives statistically relevant results regarding which variables are likely to increase or decrease the dependent variable's effect (Uzunoz & Akcay 2012).

Several studies (Braun 2010; Sopha et al. 2011; Michelsen & Madlener 2012; Mislimshoeva et al. 2014) related with factors effecting in using the briquettes and pellets in different countries used the binary probit model. In this research also was used binary probit model to determine the factors likely influence interest of using the briquettes and pellets in presented study target area. Interest of respondent was described as binary variable with the value 1 if respondent interested and is value 0 if respondent is not interested. In the following form was used the binary probit model.

$$Y_{ik} = \beta_1 X_i + \varepsilon_i \quad \textbf{(12)}$$

Where:

Y_{ik} – is a dependant variable where k donates if the respondents is interested in using the briquettes and pellets;

X_i – represents a set of all explanatory variables;

B_1 – is a vector of estimated parameters;

ε_i – is an error term;

The system of equations describing binary choices of respondent of survey is following:

$$y_i^* = \begin{cases} 1 if y_i^* > 0 \\ 0 if y_i^* \leq 0 \end{cases} \quad \textbf{(13)}$$

Also, for better understanding of possible changes the marginal effect was used. The marginal effect defines whether the variable depends whether there is an explanatory shift.

4.8.4.1 Multicollinearity

A variance inflation factor (VIF) to test for the presence of multicollinearity. Multicollinearity is a potential issue since the empirical model includes many independent explanatory variables. Even though collinearity does not bias parameter estimates, the standard errors may be affected. In addition, the model becomes sensitive to variations in sample size or model structure (Greene 2002). Several recommendations on the valuation of VIF and the level of sensitivity have been proposed. Most commonly, the value of 10 as the maximum level of VIF and the value of 0.10 as the minimum level of tolerance was recommended (Kleinbaum et al. 2013). The minimum number of tolerance 0.20 or 0.25 is suggested in the literature (Huber & Stephens 1993).

4.8.4.2 Description of Explanatory Variables

Explanatory variables used in the model are presented in Table 10. The variables provide the socio-economic and spatial characteristics of the respondents. Specific explanatory variables have been identified: age of the household head, education of the household head (primary and secondary school), urban area, household income, household size, scarcity of energy and knowledge of briquettes and pellets. Every variable and the reason for its inclusion in the model is defined below and summarized in Table 10.

Age of the household head is a continuous variable denoting age of HH head in years. Several researchers has reported that age of the respondents is major factor has influence to intention of using the briquettes and pellets in the future (Sopha et al. 2011; Michelsen & Madlener 2012). Generally, younger population are more open to use renewable energy (in form of briquettes and pellets) for heating, cooking etc. for older people it's a bit harder to change their behavior because their become used to their heating system (Sopha et al. 2011).

Education of household head (primary and secondary school) in our model education level of the household head was used in the following form:

- Completed no or primary level of education (yes = 1, no = 0)
- Completed secondary level of education (yes = 1, no = 0)
- Completed college and university degree (yes = 1, no = 0)

Education level of the household head is influencing parameters in order to making the decision to intention to use briquettes and pellets in the future also, several researchers has reported (Sopha et al. 2011; Michelsen & Madlener 2012) homeowners or household head with the higher education are expected to decide to use renewable source of energy for their house (heating, cooking and for boilers etc.).

Locality is a binary variable representing the place of the survey has been collected. In our model survey has been collected from urban and rural area of north part of the Tajikistan (Sughd region). Rural area of the north part of Tajikistan is coded as 0 and urban area of Sughd region is coded as 1. Selected variable (locality rural and urban area) can influence to intention to use of the renewable source of energy (in form of briquettes and pellets). For more description of locality (rural and urban area) please see ***4.8.1. target area*** section.

Household income is another important variable which has influence to intention to use of the renewable source (in form of briquets and pellets) of energy in rural and urban area. In this research household income is divided into 6 portions (Table 10). Also, many scientists have been mentioned that household income is a one of the main factors effecting to choosing the source of energy for heating, cooking, etc. Generally, family with higher income have more choices to choose source of energy. Apparently, households with higher income helps to transfer from traditional fossil fuels to modern fuels (Démurger & Fournier 2011). Additionally, technology, infrastructure and market access as well the price of the modern fuels are important factors to intention to use of the briquettes and pellets in the future (Nnaji et al. 2014).

Households size also, influencing factor which can affect to intention to use the briquettes and pellets in the future. Generally, family with a greater number of households spends more money on energy, at the same time family consider about the saving money on energy. In our research model number of households is a numerical variable. According to (Démurger & Fournier 2011) positively effects number of family members to firewood consumption.

Scarcity of energy is a binary variable which has influence to making the decision on using the briquettes and pellets in the future. In our research energy scarcity is coded 0 if no energy scarcity and coded as 1 if yes. According to reports and government of Tajikistan during the winter in rural area exist the energy scarcity. (Mislimshoeva et al. 2014) reported the energy shortage has massive influence on economic situation at the same time puts effort to scientists, researchers and population to find out new source of energy. Also, in western part of Pamir mountains regions in Tajikistan energy scarcity has negative influence on environment.

Knowledge of briquettes and pellets is nominal (binary) variable presenting the knowledge of the respondent about the renewable source of energy (in form of briquettes and pellets) and technologies. Knowing the briquettes and pellets can affect to intention to use it in the future. In this research knowledge of briquettes and pellets coded as 1 is yes and 0 if no. Biofuel knowledge is clearly linked to knowledge on pellets and people who know about pellets are well informed about their characteristics and benefits. In contrast, the choice of a pellet boiler is not associated with environmental involvement. Economic factors when choosing a heating system were identified as key (García-Maroto et al. 2015).

Table 10 Definition and description of variables used in the model

Variables	Description	Mean.	SD
Age	Age of the household head (years)	45.48	9.36
Primary education	Household head completed primary education (yes = 1 / no = 0)	0.11	0.31

Secondary education	Household head completed secondary education (yes = 1 / no = 0)	0.35	0.48
Urban area	Respondent's place of living (yes = 1 / no = 0)	0.46	0.50
Household income	0 – 500 somoni (categorial variable, coded as 0 -5 where 0 = 0-500 somoni and 5= more than 2500 somoni)	0.01	0.11
	501 – 1000 somoni	0.04	0.19
	1001 – 1500 somoni	0.09	0.29
	1501 – 2000 somoni	0.20	0.40
	2001 – 2500 somoni	0.22	0.42
	More than 2500 somoni	0.44	0.50
Household size	Number of members living in household	5.38	1.72
Knowledge of briquettes and pellets	Knowledge of briquettes and pellets (yes = 1 / no = 0)	0.22	0.42
Scarcity of energy	Respondent experienced a period of heating materials scarcity (yes = 1 / no = 0)	0.13	0.34

Source (Author 2020)

5 Result and discussion

In this chapter presented the results and outcomes from the laboratory experiments and compared with the objectives of the research and relevant studies, international standards (ISO) and European standards (EN). The outcome results for cotton bushes and apricot tree branches in the first place to comparing with other studies. Most results were determined as arithmetic means with the limit on repetitiveness of existing biofuels. It is necessary keep in mind that briquettes and pellets produced from other type of raw materials can be made under different condition, but the biofuels are still comparable.

The examining of the results begins with the physical properties of the cotton bush and apricot tree branches (after pruning) due to directly connection with the combustion of the biomass, such as ***moisture content, calorific value (GCV, NCV), ash content***. Also, chemical properties of the raw material are presented in this chapter: ***determination of the heavy metal and CNH content*** of the biomass**.** Later, ***determination of the mechanical durability*** of the biofuels presented and compared with other related type of materials, which is belongs to mechanical properties. Further, ***calculation of the energetic potential*** of the cotton bushes and apricot tree branches (after pruning) for whole country.

At the end of the chapter the result of the questionnaire also will be present and compare with other relevant research belongs to energy use in rural area of the Republic of Tajikistan.

5.1 Moisture content

The calculation of moisture content in the briquet and pellet quality assay is considered one of the most important tests since the moisture content of feedstocks influences the final quality of the product and stability of the briquettes and pellets formed (Dinesha et al. 2019). At the same time high percentage of the moisture content in biomass has negative influence to the combustion and the production process (Tumuluru et al. 2011). Also, opposite the lower moisture content needs more energy to produce the briquettes and pellets. For instance a suitable moisture content level is important for production the briquettes and pellets (Döring 2013; Dinesha et al. 2019). The result of the moisture content of the cotton bush and apricot tree branches (after pruning) is presented in following Table 11.

Table 11. Moisture content of cotton bush and apricot tree branches

Materials	**Unit**	**Moisture content, %**
Cotton bush $_{(a.r.)}$	wt%,	6.70 ± 0.03
Apricot tree branches $_{(a.r.)}$	wt%	6.19 ± 0.06

a.r. – as received, wt% - percentage by weight, ± - standard deviation

Source (Author 2016)

From the presented result is visible the moisture content of the cotton bush and apricot tree branched is fully responds to the A1 class (BS EN ISO 17225-6 2014; BSI EN ISO 17225-

7 2014; BSI EN ISO 17225–2 2014; BSI EN ISO 17225–3 2014) of the graded wooden and nonwooden pellets and briquettes even though the cotton bushes considered as nonwooden type of biomass. According to (Ivanova et al. 2014), the moisture content of biomass for the production of densified biofuels should not exceed 20 %, and the required moisture content as received from graded wood pellets should be almost 10 % (BSI EN ISO 17225–2 2014) and a maximum of 12 % or up to 15 % moisture content is recommended for different quality classes of graded wood briquettes (BSI EN ISO 17225–3 2014). The moisture content of biomass is largely affected by the relative air humidity and other drying conditions (Ivanova et al. 2018). Because, as a rule, biological breakdown and conversion processes of biomass are only triggered by water content that clearly exceeds 16 %–associated with energy losses–there is no acute hazard in pellets (Döring 2013). Moisture content of other type of raw materials reported by different researchers are presented in the following Table 12.

Table 12. Moisture content of the cotton bush and apricot tree branches equating with other raw materials

Materials	Moisture content, %	Source
Rice straw	15.5	(Dinesha et al. 2019)
Corn stalk	7.7	(Dinesha et al. 2019)
Corn Stover	5.4	(Kaliyan & Morey 2010)
Apple tree	6.09	(Bilandzija et al. 2012)
Cotton stalk	7.87	(Zheng et al. 2008)
Cotton stalk	12.0	(Dinesha et al. 2019)
Cotton stalk	12.0	(Chen et al. 2009)
Wheat straw	14.6	(Dinesha et al. 2019)
Apricot tree	6.09	(Bilandzija et al. 2012)
Coffee husk	15.0	(Chen et al. 2009)
Sugar cane	8.05	(Brunerová et al. 2018)

Sawdust	8.52	(Dinesha et al. 2019)
Coal	9.15	(Tortosa Masiá et al. 2007)
Walnut	3.65	(Bilandzija et al. 2012)
Poplar wood	1.0	(Kok & Özgür 2013)
Plum	5.94	(Bilandzija et al. 2012)
Cotton stalk	23.0	(Hamawand et al. 2016b)

Overall, from table is visible that moisture content of the apricot tree reported by (Bilandzija et al. 2012) is a bit lower from ours, but unfortunately no information about the origin of the materials. Also, another researchers reported the moisture content of the cotton stalk (Zheng et al. 2008) is a bit higher from our result and other also reported a much higher due to different condition of growing the cotton. According the European standards (presented above) the moisture content of the biomass should not exceed the 15 %. Based on (Ungureanu et al. 2018) optimal moisture content for the woody material is 5 – 10 %. Overall assessment of the measured moisture content and the secondary data used to compare it can be concluded that the level of moisture content of residual cotton bush and apricot tree branches (after pruning) corresponds to the required technical norm.

5.2 Ash content

Ash content as well one of the important parameters of the biofuels, which requires by the standards. Ash content in our research has been determined according the standards (***see section methodology***). The amount of ash from solid fuels influences both pollutant emissions and the technological design and construction of the combustion plant. In general, with increased ash content of the fuel, the chance of sintering / scoring (slagging) in the fire bed is increased (Döring 2013). The result of the experiments for determination of the ash content the cotton bushes and apricot tree branches (after pruning) is presented in the Table 12 and compared with other researchers.

Table 13. Comparing the ash content of the biomass with related type of biomass

Materials	Ash content (AC), %	Source
Cotton bush$_{(d.b.)}$	**3.22 ± 0.13**	**(Author 2016)**
Apricot tree branches$_{(d.b.)}$	**1.71 ± 0.05**	**(Author 2018)**
Wheat straw	5.2	(Lunguleasa & Spirchez 2015)
Vine wood waste	3.46	(Muzikant & Havrland 2010)
Olive tree branches	3.78	(García-Maraver et al. 2014)
Cotton stalks	9.4	(Dinesha et al. 2019)
Cotton husk	6.0	(Dinesha et al. 2019)
Apricot$_{(d.b.)}$	1.99	(Bilandzija et al. 2012)

d.b. – dry basis, ± - standard deviation

Presented result and comparison with other authors from the table also visualized in the form of graph (Figure 29).

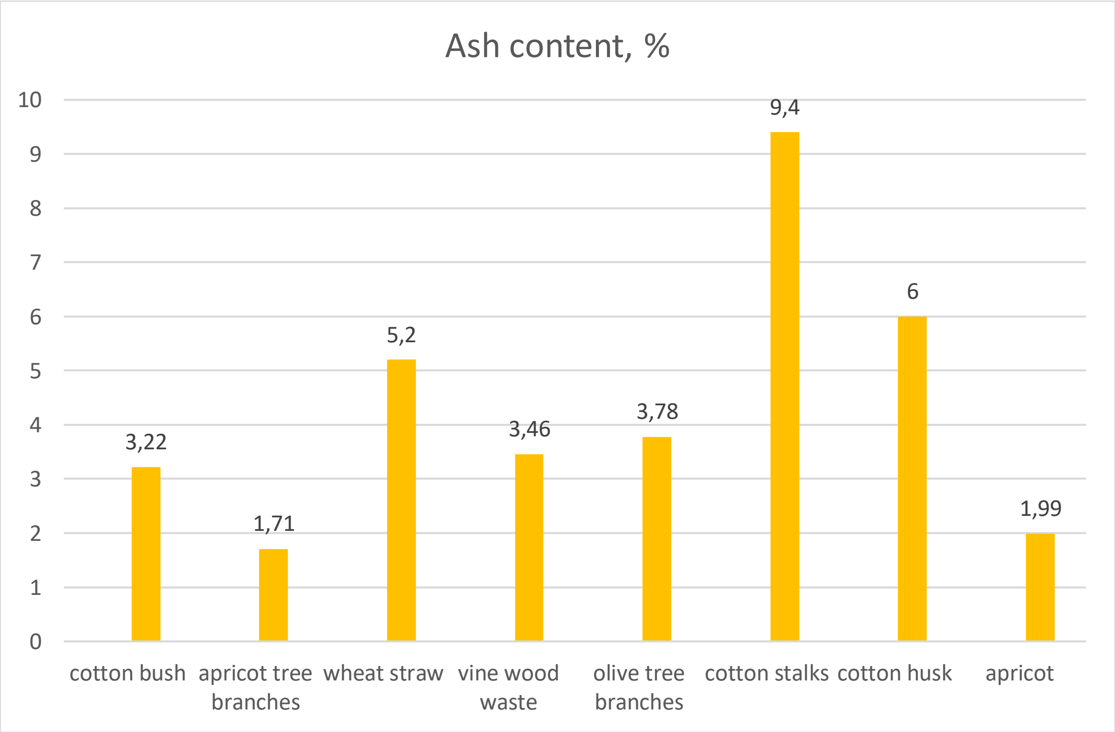

Figure 29. Comparing the ash content of biomass with other type of raw material

Source (see table 13)

From the **Table 13** it is visible that pellets from cotton residues do not meet A1 class requirements of graded wood pellets, specifically due to high ash content and briquettes is at least three times higher than ash content of graded wooden biofuels, but twice lower than required one for non-wooden pellets and briquettes. (Avelar et al. 2016) have measured dry basis ash content of biofuels made of cotton residues 8.93 %, which is much higher (three times) than ash content measured in this research, but textile industry residues were used in that case. For example, in comparison to ash content of rice straw 9.44 % (Yang et al. 2016) or brown coal 10.94 % (Kim et al. 2001) content of ash in cotton wastes is significantly lower. According to (Kim et al. 2001) high ash content causes high dust emissions and negatively affects combustion efficiency. Three other researches have presented very different values of cotton stalk waste's ash content (as received): 2.54 % (Chen et al. 2017a), 14.80 % (Mythili & Venkatachalam 2013) up to 17.3 % (Hamawand et al. 2016a). This difference can be probably explained by different origin of biomass (different soil conditions), different varieties or amounts of used defoliants.

The amount of ash can affect the operation of a combustion devise as well as the time spent for the ash removal as it has an influence on deposit formation in the boilers (Kamperidou et al. 2017). That is why the content of ash should be known, and it is regulated by the modern standards of biofuel quality (Lunguleasa & Spirchez 2015). **Table 13** shows that the ash content of apricot waste is significantly lower in contrast to other materials. However, in comparison with the standard requirement for graded wood briquettes and pellets, the measured ash content in apricot biomass exceeds the limits for class A biofuels, but fully fulfils the requirement for class B (AC dry basis ≤ 2 % for pellets and AC dry basis ≤ 3 % for wood briquettes).

5.3 Volatile matter

Volatile matter of the biofuels is another parameter which requires to identify. Determination of the volatile matter of cotton bush and apricot tree branches has been done according the presented standards (***see methodology section***). Volatile constituents are gaseous compounds that escape when a fuel is heated under specified conditions. These consist primarily of fuel gasses and act to some degree as indicator of the ignitability of the fuels in a combustion plant (Döring 2013). In our experiments volatile matter of the cotton bush in dry basis was 88.4 ± 1.55 % and for apricot tree branches in dry basis was 73.2 %. Based on another researcher (Hamawand et al. 2016a) volatile matter of the cotton stalk 65.4 % its due to different location or the growing the cotton and different soil condition. Volatile matter of apricot tree 74.42 % was find out by (Bilandzija et al. 2012) also by the same researcher was reported volatile matter of the different woody materials which is apple tree 73.50 %, Pear tree 73.86 %. (Zheng et al. 2008) also determined the volatile matter for cotton stalk and reported 69.54 %. Another research on volatile matter of the cotton textile industry residues 90.2 % was identified by (Avelar et al. 2016).

5.4 Gross and Net calorific value

Ultimately, pellets and briquettes calorific value depends on process conditions such as temperature, particle size, and pretreatment feed. Pellets with higher densities usually have higher calorific value. The average calorific value of wood and straw-based pellets ranges between 17–18 MJ kg^{-1} (Tumuluru et al. 2011). The heating value is the amount of heat released with the complete oxidation of a liquid, without taking into account the condensation effect of the water vapor in the smoke (Döring 2013). Determination of the calorific value is a required for biofuels and major parameter. The outcome of the gross calorific value (GCV) and net calorific value (NCV) of the cotton bush dry basis and apricot tree branches dry basis are comparable with other materials and visualized in the following Table 14.

Table 14. GCV and NCV of the cotton bush and apricot tree branches comparison with other type of biomass

Materials	GCV, (MJ kg^{-1})	NCV, (MJ kg^{-1})	Source
Cotton bush$_{(d.b.)}$	**18.93 ± 0.08**	**17.69 ± 0.07**	**(Author 2016)**
Apricot tree branches$_{(d.b.)}$	**20.47 ± 0.04**	**19.29 ± 0.06**	**(Author 2018)**
Rubber shell	15.97	13.60	(Egbu & Simonyan 2017)
Almond shell	19.56$_{(d.b.)}$	17.16$_{(a.r.)}$	(García et al. 2019)
Cotton plant main stem	17.79	-	(Gravalos et al. 2016)

Cotton plant terminal bud	16.64	-	(Gravalos et al. 2016)
Cotton plant leaves	16.12	-	(Gravalos et al. 2016)
Apricot kernel	18.64	-	(Gravalos et al. 2016)
Wheat straw	16.86	15.55	(Bradna et al. 2016)
Wine wood waste	19.47	18.87	(Spinelli et al. 2012; Cosereanu et al. 2015)
Cedrus atlantica	20.36	-	(Telmo & Lousada 2011)
Spruce wood (with bark)	18.8	-	(Kaltschmitt et al. 2003)
Cotton textile industrial residues	17.9	16.7	(Avelar et al. 2016)
Apple tree		17.06	(Bilandzija et al. 2012)
Apricot tree		17.19	(Bilandzija et al. 2012)
Apricot branches	20.5	19.1	(Cichy et al. 2017)
Walnut branches	19.3	17.9	(Cichy et al. 2017)

d.b. – dry basis, a.r. – as received, ± - standard deviation

According to (Coates 2000) and (Hamawand et al. 2016b) GCVa.r. of cotton stalks ranges from 17.1 to 18.1 MJ kg-1, which is in correspondence with the present research results. GCVd.b. of cotton textile industry residues (CGT) published by (Avelar et al. 2016) is 17.9 MJ kg^{-1} and NCVd.b. is 16.7 MJ kg^{-1}, i.e. the values are lower than the measured values. This can be explained by different composition of CGT. According to (Egbuta et al. 2017) CGT contains of leaves, fiber, flowers, immature seeds, sticks and soil, and more attention was previously given to CGT utilization because it is centrally stockpiled at gins and collected with existing infrastructure. Comparing to another typical raw material used for solid biofuels production: GCVd.b. of cotton biomass is higher than the average calorific value of a mixture of wheat and rape straw 15.3 MJ kg^{-1} (Niedziółka et al. 2015), it is almost equal to the value of Miscanthus

19 MJ kg^{-1}, but lower than GCVd.b. of wood logging residues 19.7 MJ kg^{-1} (broad-leaf wood) and 20.5 MJ kg^{-1} (coniferous wood) (BS EN ISO 17225 - 1 2014). In comparison, fossil nonrenewable brown coal has GCVd.b 22.3 MJ kg^{-1} (Tsuchiya & Yoshida 2017).

In agreement with many studies performed by different researches, e.g., (Cosereanu et al. 2015) and (Kamperidou et al. 2017), it was found that herbaceous biomass typically has a lower calorific value than wood biomass. From **Table 14**, it can be observed that the gross and net calorific values of apricot wood waste are the highest in comparison with other sources of biomass that could also be generated in Tajikistan in large quantities. According to the standard requirement (BSI EN ISO 17225–2 2014; BSI EN ISO 17225–3 2014), NCV as received of the best quality class A1 graded wood pellets should be ≥ 16.5 MJ kg^{-1} and ≥ 15.5 MJ kg^{-1} for briquettes, which would be fulfilled in the case of the tested apricot material. The (Kaltschmitt et al. 2003) reports net calorific value (NCV) of the wood decreases approximately from 18.5 MJ kg^{-1} when increasing the water content and net calorific value (NCV) is zero when approximately when the water content is 88 %. The net calorific value (NCV) of vine pruning's ranges from 18.74 to 19.19 MJ kg^{-1} which higher to compare with other well known biomass fuels (Nasser et al. 2013)

Conclusion the result of the calorific value of the cotton bush and apricot tree branches and compering them with other materials and European standards, shows the great value and considered to be a promising energy source.

5.5 Carbon, Hydrogen, Nitrogen content

The primary chemical composition of waste biomass affects their calorific value and behavior during combustion of subsequent biofuels. The bigger percentage of the carbon (C) and hydrogen (H) in biomass shows the better calorific value of the raw material (Anggono et al. 2018). For thermo-chemical conversion the characteristics of solid fuels specific to energy sources are primarily relevant and depend greatly on the basic composition of the fuels under consideration (Döring 2013). The result from experiments to determination of the CHN content of the cotton bush and apricot tree branches (after pruning) is presented and compared with other relevant studies. CHN content of the biomass is visualized in the Table 15.

Table 15. CHN content of the cotton bush and apricot tree branches

Parameters	Cotton bush$_{(d.b.)}$	Apricot tree branches$_{(d.b.)}$
Carbon, %	48.56 ± 0.12	47.28 ± 0.21
Hydrogen, %	5.69 ± 0.02	6.27 ± 0.03
Nitrogen, %	0.90 ± 0.01	0.36 ± 0.009

d.b. – dry basis, ± - standard deviation

Source (Author 2020)

High nitrogen content in the fuel can negatively affect formation of harmful emissions, mainly nitrogen oxides (NOx, principally NO) (Tumuluru et al. 2012). However, it was found several studies (Sun et al. 2008a, 2008b) dedicated to the combustion of poor cotton stalks, which have been considered the pollutant emissions of NO (NO emission ranged from 110–153 ppm, at 6 % oxygen concentration; NO_2 emission were negligible – less than 1 ppm). Additionally, (Sun et al. 2008b) observed a close linkage between the oxygen and NO emissions, so the emissions may be reduced by appropriate measures, e.g. air staging. (Coates 2000; Hamawand et al. 2016b) have also published that cotton stalks are characterized by the highest burning efficiency and longest burn time in comparison with other residues such as corn stover and soybean.

The research also indicated the basic element content in apricot pruning waste (see Table). According to (Ivanova et al. 2018), the hydrogen content in wood biomass is usually around 6%. The nitrogen content in the biofuels is listed among the necessary stated parameters, as nitrogen has a direct impact on the formation of harmful nitrogen oxides (NOx) during fuel combustion (Erisman et al. 2010; Ivanova et al. 2018). Table 14 shows that, from the viewpoint of N content, the apricot waste biomass is the cleanest in comparison with the other selected materials. In accordance with strict limits for graded wood briquettes as well as pellets, the N content on a dry basis is ≤ 0.3 % for class A1 solid biofuels, ≤ 0.5 % for class A2 and ≤ 1 % for class B. Thus, apricot wood waste exceeds the class A1 requirements, but fulfils the A2 limits.

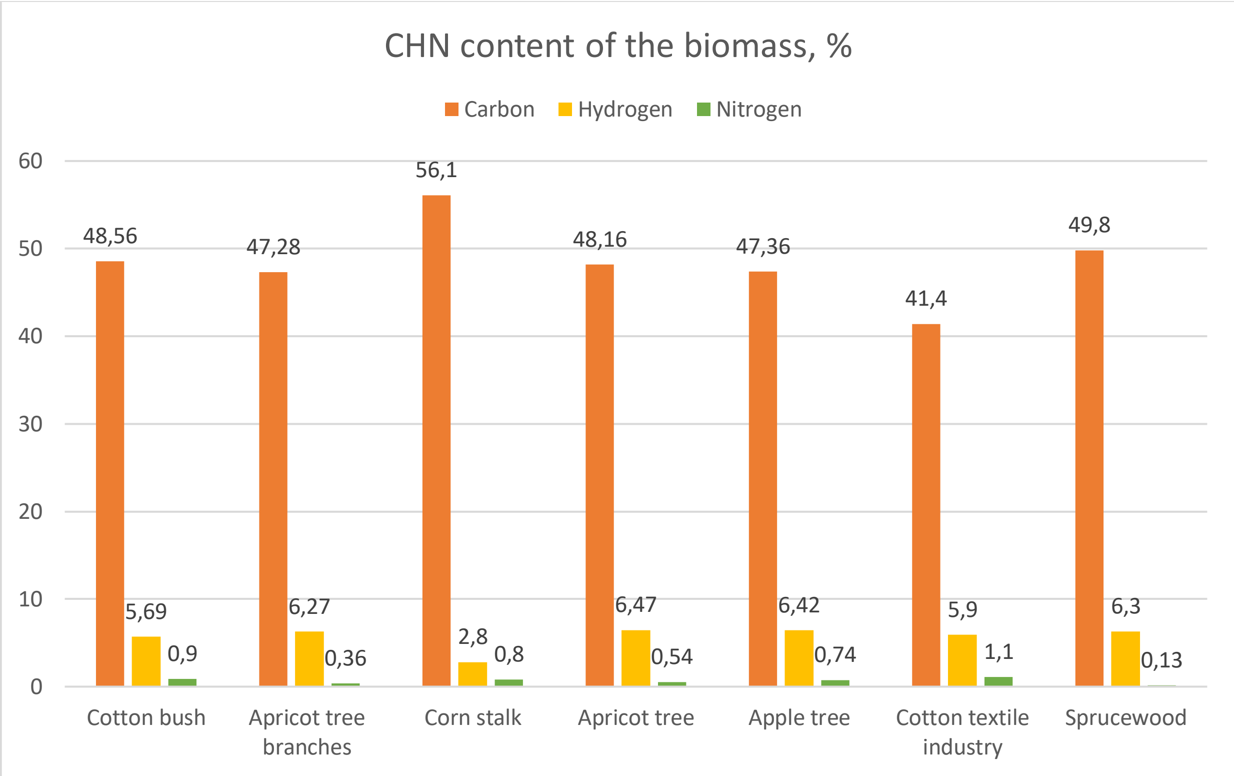

Figure 30. CHN content of the cotton bush and apricot tree branches comparing with different selected biomass

Source (Author 2016, 2018), (Minowa et al. 1998), (Bilandzija et al. 2012), (Avelar et al. 2016), (Kaltschmitt et al. 2003)

5.6 Heavy metal determination

Determination of the heavy metal of the cotton bush and apricot tree branches is a part of the chemical properties of the raw material. During the laboratory experiment following elements Chromium (Cr), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As), Cadmium (Cd), Mercury (Hg) and Lead (Pb). were determined based on (BS EN ISO 16968 2015). The result of the determination of heavy metal is noted in the following Table 16.

Table 16. Heavy metal of the cotton bush and apricot tree branches, mg kg^{-1}

Materials	**Ni**	**Cu**	**Zn**	**As**	**Cd**	**Pb**	**Hg**	**Cr**	**Source**
Cotton bush$_{(d.b.)}$	1.170 ± 0.063	3.082 ± 0.09	5.885 ± 0.089	0.081 ± 0.010	0.009 ± 0.008	0.170 ± 0.011	0.002 ± 0.004	0.090 ± 0.033	(Author 2016)

Apricot tree branches$_{(d.b.)}$	0.446 ± 0.051	2.06 ± 0.01	6.90 ± 0.07	0.057 ± 0.012	0.005 ± 0.007	0.122 ± 0.010	0.035 ± 0.005	0.843 ± 0.079	(Author 2020)

d.b. – dry basis, ± - standard deviation

Source (Author 2020)

Naturally, biofuels produced from different types of biomass show heavy metal values according to their origin. Various requirements must therefore be met in order to maintain the quality of the biofuels. In accordance with obligatory technical standards, the applicable values of heavy metals in pellets and briquettes of different biomass (BS EN ISO 17225-6 2014; BSI EN ISO 17225-7 2014; BSI EN ISO 17225–2 2014; BSI EN ISO 17225–3 2014). In the following Table 17 is presented the heavy metal of the biomass observed by different researcher and compared with our result and European standards.

Table 17. Heavy metal contents of selected biomass and comparison with European standards (EN ISO)

Elements$_{(d.b.)}$	**Wooden material[1]**	**Nonwooden materials[2]**	**Sunflower shell[3]**	**Jatropha seed cakes[4]**
As, mg kg^{-1}	≤ 1	≤ 1	5.1	0.030
Cd, mg kg^{-1}	≤ 0,5	≤ 0,5	7.1	0.004
Cr, mg kg^{-1}	≤ 10	≤ 20	47.3	0.135
Cu, mg kg^{-1}	≤ 10	≤ 20	261	7.601
Pb, mg kg^{-1}	≤ 10	≤ 10	168	0.147
Hg, mg kg^{-1}	≤ 0,1	≤ 0,1	0.4	0.010
Ni, mg kg^{-1}	≤ 10	≤ 10	29.5	0.307
Zn, mg kg^{-1}	≤ 100	≤ 100	1.250	17.150

d.b. dry basis, Source [1](BSI EN ISO 17225–2 2014), [2](BS EN ISO 17225-6 2014), [3](Demirbaş 2005), [4](Vlachosova 2016)

The fact that raw material (cotton bush and apricot tree branches) used for this experimental research consisted of all feedstock classification of plant organs (also the tufts of raw cotton) is not explicitly understood according to the defined categories of biomass types. Even if the findings of the current research are compared with the values of woody and nonwoody materials. From the table is visible that sunflower shell (ash fly) has much higher reported by (Demirbaş 2005) to compare with our research due to researcher used different method to determine the heavy metal for biomass. (Pastircakova 2004) reported that Lead (Pb) in beech wood bark dry basis is 36.9 mg kg^{-1} however but using the different method determination of heavy metal and comparing with cotton bush and apricot tree branches is much higher. According to (Nzihou & Stanmore 2013) forest residues biomass has Nickel (Ni) dry basis 1.3 and Zinc (Zn) dry basis 5.7 mg kg^{-1} compare to cotton bush and apricot tree branches is not big difference and corresponds to the standards.

5.7 Mechanical durability

Mechanical durability of the biofuels is another major important parameter which requires to determine that shows the quality of produced biofuels in the form of briquetted and pellets (Alakangas 2011). Mechanical durability (also called abrasion resistance) is the key predictor of the quality of biofuels defining the capacity of biofuels samples to remain intact throughout their handling, transport and storage (Kaliyan & Vance Morey 2009; Tumuluru et al. 2015; Muazu & Stegemann 2015). Several factors affect DU such as characteristics of used raw materials. The result from the experiment of the mechanical durability of cotton bush and apricot tree branches are presented below (Table 18).

Table 18. Mechanical durability of the cotton bush and apricot tree branches compare with other selected type of biomass

Materials	Mechanical durability of pellet, %	Mechanical durability of briquettes, %
Cotton bush	**97.82[1] ± 0.12**	**97.63[1] ± 0.19**
Apricot tree branches	**94.37[1] ± 0.09**	**96.15[1] ± 0.159**
Wheat straw	94.40[2]	95.65[3]

Cotton stalk	-	99.56[4]
Soybean stalk	-	98.79[4]
Bamboo fiber	-	97.80[5]
Barley straw	95.5[6]	-

± - standard deviation, Source [1](Author 2016, 2019), [2](Zabava et al. 2018), [3](Guo et al. 2016), [4](Rajkumar & Venkatachalam 2013), [5](Brunerová et al. 2018), [6](Ungureanu et al. 2018)

In general, from **Table 18**, it is visible that the mechanical durability of cotton-based biofuels is the highest, followed by the apricot-based biofuels, then biofuels from wheat straw, and the lowest durability was reported for the briquettes from vineyard pruning biomass. The determined mechanical durability of produced apricot briquettes is similar or even higher than the average values for wood briquettes measured by (Brožek et al. 2012), i.e., the DU of poplar chip briquettes is about 94.3%. Mechanical durability is not listed among required parameters for graded wood briquettes, but it is stated for wood pellets as ≥ 97.5 % for class A and ≥ 96.5 % for class B (BSI EN ISO 17225–2 2014), which was not fulfilled.

However, the mechanical durability can be improved during the processing/pressing, e.g., a higher working pressure used for densification increases the density of the produced biofuels (Muntean et al. 2017). Several authors have tested a dependence of mechanical durability on storage conditions. For example, (Brunerová et al. 2016) have measured no difference in DU of digestate briquettes stored for nine months outdoors in contrast to indoor constant conditions; (Brožek 2013) has found that the DU of briquettes made of spruce shavings stored for a long time in closed heated rooms was on average 5 % higher than the DU of briquettes stored in closed unheated rooms; (Brožek 2014) published that if briquettes are stored in well closed leak proof plastic bags, neither the location nor the storage time influence their life time and mechanical quality; however, in the case of using net plastic bags, the damages of briquettes stored in various conditions for different storage times were monitored. The study of (Kaliyan & Vance Morey 2009) concluded that the proper relative air humidity for storage of densified products is 60 – 70 %, air temperature around 25 ^{0}C and an increase in the moisture content of densified products to more than 13 % can influence the DU negatively.

5.8 Calculation of the yearly accumulation of the biomass (cotton bush and apricot tree branches)

Determination of the biomass (cotton bush and apricot tree branches) yield was made based on reports and personally on the field. According the Tajik statistical agency under the president Republic of Tajikistan (TAJSTAT) and Ministry of agriculture in Republic of Tajikistan (MoA) in one hectare of the cotton approximately 100,000 pieces of the cotton bushes. Based on our research in laboratory we find out that one piece of the cotton bush weights around 58-62 gram. According the information reported by the Ministry of Agriculture in Republic of Tajikistan 187,500 ha of cotton has been cultivated in 2018 (Ministry of Agriculture 2018).

Also, determination of yearly amount of apricot tree branches as biomass made according the Institute of Horticulture and Gardening in Tajikistan. The schematic growth of the apricot orchard in Tajikistan is depend on the type (sort) of the apricot, but mostly common scheme (8 x 8) around 154 – 156 trees per hectare. And agrotechnical improvement of the tree happens ones or twice per year, after the pruning approximately 15 – 20 kg of the biomass is available in the field (Kamolov et al. 2010). In 2017 according the (TAJSTAT 2017) in Tajikistan 61.617 ha of the apricot orchard has been harvested. The result of the calculation of biomass (cotton bush and apricot tree branches) is presented in the following Table 19.

Table 19. The result of the calculation of the waste

Biomass	Amount of the raw material per hectare, (t)	Total amount of the waste yearly, (t $year^{-1}$)
Cotton bush	6	1,125.000
Apricot tree branches after pruning	2.73	168,241.14

Source (Author 2016, 2018)

The result from the table 19 is showing that yearly amount of the biomass (cotton bush and apricot tree branches) enough quantity which will be possible to apply for efficient production of solid biofuels in the form of briquettes and pellets. Production of solid biofuels can have a positive effect to energy sector of the Tajikistan especially in rural area. Also, other researchers reported the availability of the cotton stalks in the field and different type of tree branches after pruning. Availability of cotton stalk as biomass noted by (Hamawand et al. 2016b) is around 5.2 – 5.6 ton per hectare compare to our report is a bit lower due to different technique of growing the cotton plant. Another study about the calculation of the cotton stalks as raw material done by (Sahoo et al. 2016) and reported around the 4 ton per hectare in Georgia USA this is also lower to compare our result due to different location of cultivation and climatic area and different type (sort) of cotton plant. Another research was done in India and reported the availability of the cotton bush in whole country is 22.33 million of ton per year and also compare to our result is much higher because due to in larger scale of the cultivation of the cotton (Dubey et al. 2010). In Greece availability of the cotton stalk ranges between 3 – 7 ton per hectare reported by (Gemtos & Tsiricoglou 1999).

Table 20. Comparing the result of the apricot tree branches after pruning with other sources.

Biomass pruning, kg tree^{-1}	**(Bilandzija et al. 2012)**	**(Unal & Alibas 2007)**
Apple	2.34	34.6
Apricot	5.79	13.3
Pear	2.45	15.2
Peach	7.23	10.5
Plum	7.34	9.4
Sour cherry	5.37	21.6
Olive tree	9.08	18.1

Source (Author 2020)

From the Table 20 is visible that results are quite different but compare to our result apricot tree branches is a bit difference with researcher (Unal & Alibas 2007) it is due to different type of apricot tree (sort) and different growing scheme and density of the tree per hectare. Also, comparing with (Bilandzija et al. 2012) the results are a bit bigger different but scientist mentioning in the research paper that information or data is takin from the intensive growing orchards, the results of the calculation the biomass is still comparable. Poplars and willows are the comparison of other woody crops, which are mostly connected for energy purpose. The yield of poplars can vary from 1.57 to 47.7 t ha^{-1} of dry biomass, as noted (Carmona et al. 2015). (Stolarski et al. 2013) shows that on average, a willow tree can produce 14.1 t ha^{-1} of dry wood.

5.9 Calculation of the energy potential of biomass

Energy yield calculation is a leading purpose of this dissertation thesis. In Tajikistan, it is possible to calculate the energy yield by knowing the net calorific value (NCV) of biomass (cotton bush net calorific value 17.69 MJ kg^{-1} and apricot tree branches is 19.29 MJ kg^{-1}), the availability of raw material per hectare (for cotton bush 6 t ha^{-1} and for apricot tree branches 2,73 t ha^{-1}) and the number of cotton harvested area is 187,500 ha and apricot orchards hectare 61,617 ha it is possible to calculate the energy potential. The result of the calculation is shown in following table (Table 21).

Table 21. Calculation of the energy potential

Waste	Number of the waste per hectare, (t)	Total amount of the waste biomass per year (t)	Total of the energy yield of biomass, (TJ)
Cotton bush	6	1,125,000	19,901.25
Apricot tree branches after pruning	2.73	168,241.14	3,244.86
Total	8.73	1,293,241.14	**23,146.11**

Source (Author 2020)

From the table 21 is visible that selected biomass can help to improve the energy situation in Tajikistan. Energy potential of the cotton bush is much higher due to more accumulation of the biomass and harvested area every year. Even though energy potential of apricot tree branches is lower compare to cotton bush but still have a positive effect to energy sector of the Tajikistan. Compare with other researchers olive tree energy potential was calculated for Messenia region in Greece is 914.092 GJ per year (Sagani et al. 2014) due to lower amount of availability of the biomass and need to take to consideration this amount for one region only. According to (Stavjarska 2016b) energy potential of the cotton bush for one hectare is 93.59 GJ ha^{-1} (based on cross calorific value) and compare to our result is a bit lower, we find out the energy potential for cotton bush for hectare is 113.58 GJ ha^{-1}. (Bilandzija et al. 2012) reported energy potential from pruning biomass (different types of trees) per year is 4217.05 TJ for Croatia and apricot tree energy potential in Croatia 7.84 TJ per year, which compare to our result is much lower due to less harvested area. Energy potential of the rice husk is calculated by (Yokoyama et al. 2000) is 70,300 TJ per year for Thailand. Energy potential of the wheat and barley find out by (Ziaei et al. 2015) is 48.5 GJ ha^{-1} and 49.8 GJ ha^{-1} and compare to apricot tree branches 55.9 GJ ha^{-1} is a bit lower but taking to account that wheat and barley are not wood biomass and still comparable.

Overall energy potential of the biomass has been study for ling time and will be study in the future. In Tajikistan until now not any complex study about the biomass energy potential has been done. From the result is visible big amount of energy can be obtained from selected biomass and used for the future energy improvement condition.

5.10 Result of questionnaire survey

5.10.1 Descriptive statistics

Demographic characteristics

The result of the questionnaire survey has only supportive characteristic to this research. The demographic characteristics of respondents in target area are presented in **Table 22**. Majority of households were headed by men. The mean age of respondent was 45.48 years. More than half of the respondents had a university degree, while only less than 11 % of the respondents was illiterate achieved a primary education. The proportion of the respondents is almost equal in term of living area, more than 54% respondents were from the rural area and less than 46% of respondents were from the urban area. Almost half of the respondents had average monthly income more than 2,501 somoni (approximately 245 USD per month). More than 22% of the respondents had income between 2,001 – 2,500 somoni (approximately 195 – 245 USD per month). Only 1.2 % of the respondents had income between 0 – 500 somoni (approximately 50 USD per month) which is considered a minimum wage in Tajikistan.

Table 22. Demographic characteristics of respondents (n = 85)

Variable	Description	Percentage
Head of household gender	Male	93
	Female	7
Age of the household head	18 – 24	2.35
	25 – 39	18.82
	40 – 54	68.23
	55 +	10.58
Living area	Rural area	54.11
	Urban area	45.88
Education of the household head	Illiterate	3.52
	Primary school	7.05
	Secondary school	35.29
	University degree	54.11
Family income	0 – 500 somoni	1.12
	501 – 1000 somoni	3.5
	1001 – 1500 somoni	9.4
	1501 – 2000 somoni	20
	2001 – 2500 somoni	22.4
	More than 2500 somoni	43.5

Source: (Author 2020)

Energy use for heating during the heating period

Further the results of the energy use for heating during the heating period are presented, including the rural as well as urban area. Majority of respondents used the electricity for heating the houses and using the wood and coal for heating purpose is almost equal. About 15 % of respondents used the natural gas for heating the houses. Usage of the briquettes and pellets for heating the houses is minimal, only slightly more than 5 % of the respondents mentioned the other type of heating source. In the following Figure 31 the energy use in rural and urban area is presented.

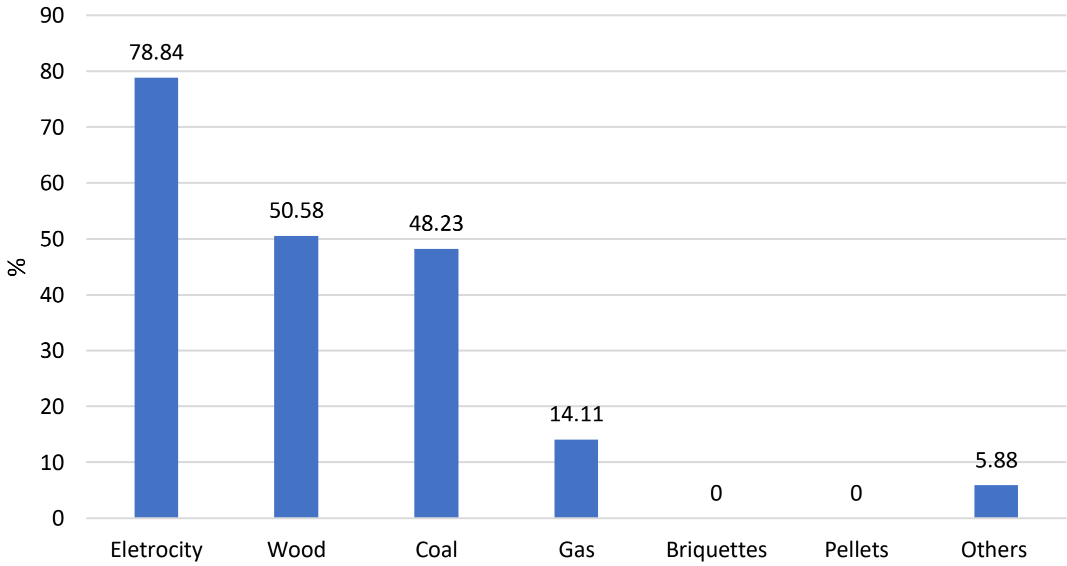

Figure 31. Type of energy use for heating (n = 85)

Source (Author 2020)

In the Figure 32 is presented the frequency of using the energy for heating period. Respondents replied that 54.11 % used very often the electricity and wood type of energy used 24.7% of them very often. About 25% of respondents used the coal type of energy during the heating period and the gas type of energy was rarely used - only 3.52 % used it during the heating period.

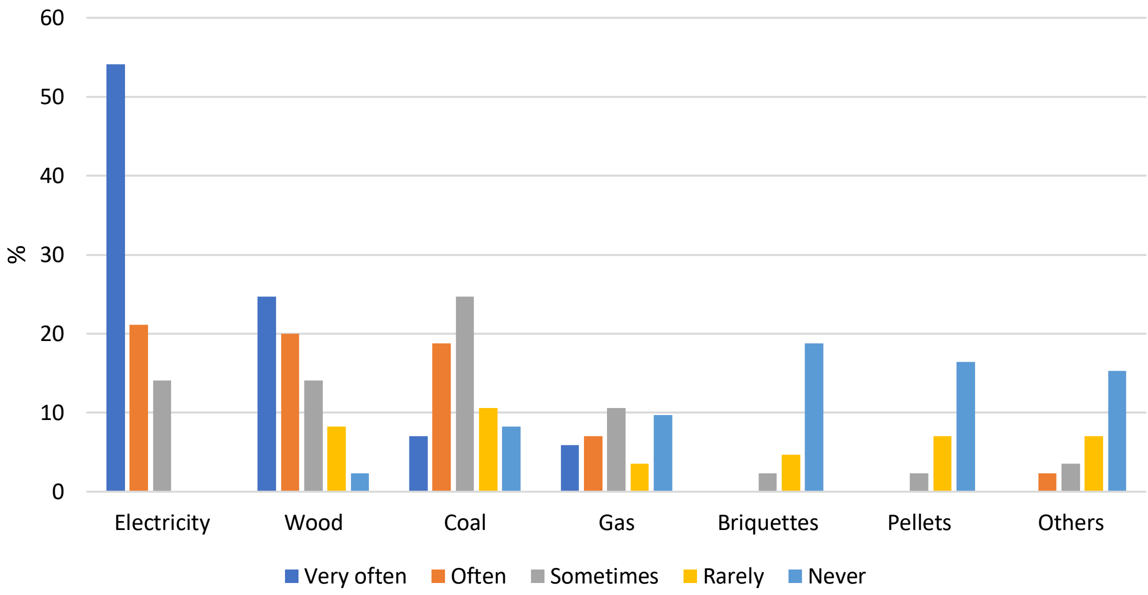

Figure 32. The frequency of using type of energy during the heating period (n = 85)

Source (Author 2020)

Further, the quantity of the energy purchase during the heating period is visualized. From the Figure 33 is visible that 28 % of the respondents purchased between 0 – 500 kg of material per heating season and 25 % of them buy the heating material in range between 501 – 1,000 kg per heating period. Only 8 % of the respondents reported the purchasing the heating material ranges between 1,501 – 2,000 kg for seasonal heating. The majority of the respondents mentioned that no energy scarcity they felt during the heating time, but only 12 % of them reported they feel energy scarcity during the winter, (mentioned mostly for electricity, wood and coal).

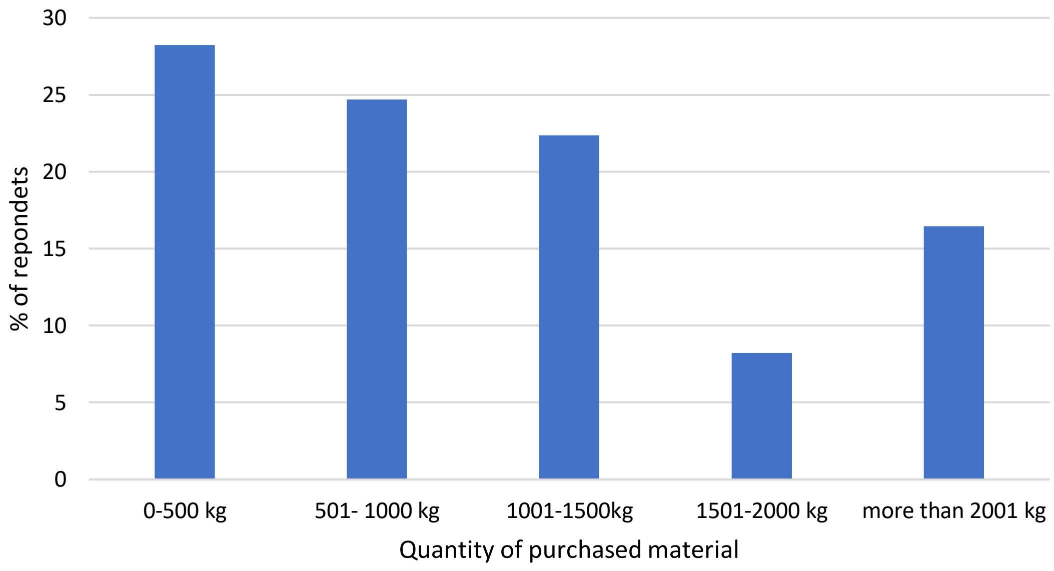

Figure 33. Purchasing the heating material per season (n = 85)

Source (Author)

In the (Figure 34) the expenditure for all type of energy for heating season is shown. About 27 % of the respondents spend between 501 – 700 somoni per heating season. Only 7 % of the respondents spend money more than 2,001 somoni for energy during the heating season.

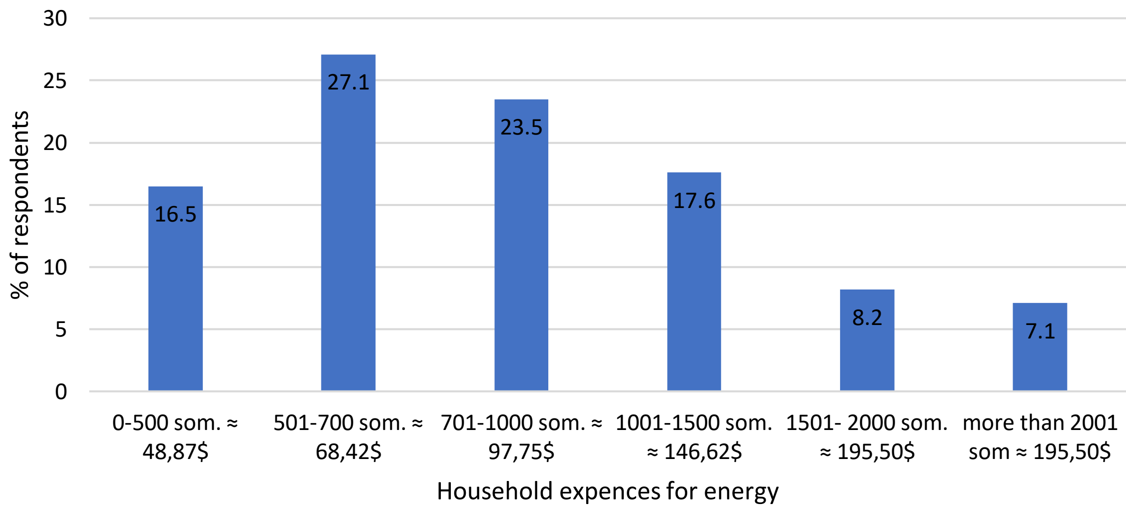

Figure 34. Household expenses for energy during the heating season (n = 85)

Source (Author)

Since the p – value (0.003) is less than the significance level (0.05), we cannot accept the null hypothesis. Thus, we can conclude that there is a relationship between household income, energy scarcity and intention to use of biofuels in form of briquettes and pellets in the future. However, there was no found relationship between educational level of household head and intention to use briquettes and pellets in the future.

Table 23. Result of the Fisher exact test is noted in the following table (n = 85)

	Degrees of freedom	**Fisher exact test**	**p - value**
Education of HH head	2	2.478	0.342
HH income	5	14.541	0.003
Energy scarcity	1	11.296	0.003

Note: Fisher exact test was used instead of Chi^2 test because the expected frequency was lower than five

Source (Author 2020)

5.10.2 Analytical result of binary probit model

In this section is presented the result of binary probit model and factors likely influencing to intention of using the briquettes and pellets in the future in north regions of Tajikistan. Result of binary probit model is shown in Table 25. Firstly, the regression model was tested for multicollinearity by use of a variance inflation factor (VIF); the results are presented in Table 24.

Table 24 Variance inflation factor (VIF)

Variables	**VIF**	**1 / VIF**
Age of the HH	1.15	0.87
Primary education	1.16	0.86
Secondary education	1.12	0.89
Urban area	1.20	0.83
HH income	1.10	0.91
HH size	1.20	0.83

Scarcity of energy	1.12	0.90
Knowledge of briq. and pell.	1.10	0.91
Mean VIF	1.14	

Source (Author 2020)

All tested explanatory variables have VIF values within the range of 1.10 - 1.20. Mean VIF is 1.14 which is below the threshold value of ten suggested by (Kleinbaum et al. 2013). The results reveal that there is no significant multicollinearity among the explanatory and dependent variables in the model.

Table 25 Result of binary probit model – intention of respondents to use briquettes and pellets in the future (n = 85)

Variable	**Coefficient**	**Standard error**	**p - value**	**Marginal effect**
Age of the HH head	0.010	0.015	0.502	0.002
Primary education	0.748	0.608	0.219	0.159
Secondary education	-0.547	0.357	0.126	-0.116
Urban area	0.480	0.371	0.196	0.102
HH income	**-0.384**	**0.123**	**0.002**	**-0.082**
HH size	**0.323**	**0.099**	**0.001**	**0.069**
Scarcity of energy	**1.724**	**0.592**	**0.004**	**0.367**
Knowledge of briquettes and pellets	**0.811**	**0.362**	**0.025**	**0.176**
Constant	-2.219	0.804	0.006	
Wald chi2 (8)	20.34			
Prob > chi2	0.009			

Pseudo R2	0.302
No. of respondents	85

Source (Author 2020)

The Chi^2 results of probit model show that likelihood ratio statistics are highly significant (Prob > chi^2 = 0.009) suggesting that the model have a strong explanatory power. Result from the table is visible that household income, household size, scarcity of energy and knowledge of briquettes and pellets influence the intention to use of briquettes and pellets in the future. Area of residence, age and education of household head did not show a significant effect.

The coefficient of household income was negative and showed that respondents with higher income are less interested to use the briquettes and pellets in the future and coefficient was statistically significant. Also, same result has been reported by (Michelsen & Madlener 2012). Result of study (Sopha et al. 2011) shows that respondents with higher income living in urban area in Norway also are less intended to use pellets heating system at home. Case study of using the firewood in China has showed that population with higher income are using less firewood also, showing the negative coefficient and statistically significant (Démurger & Fournier 2011).

The binary probit model shows that household size has a positive coefficient and statistically significant that means respondent with higher number of households have an intention to use the briquettes and pellets in the future. Similar study in case of using the renewable energy (in form of biogas) has reported that families with higher number of household members are want to use the renewable energy for cooking and boilers equipment (Shen et al. 2015). Also, another researcher reported that in case of using the firewood for cooking, number of households has a positive effect in Nigeria (Nnaji et al. 2014).

Energy scarcity was found to play important role, the variable has a positive and statistically significant effect, suggesting the energy scarcity increase an intention to use the briquettes and pellets. Compare the result of the binary probit model with other researcher (Mislimshoeva et al. 2014) published that scarcity of energy (electricity) in western part of the Pamir affect the population negatively from economic and environmental side. Also, it is logic when household or community have an energy shortage it pushes the population to think new source of energy.

In our binary probit model another factor which shows positive coefficient and statistically significant that means respondents which knows (or believe they know) the briquettes and pellets have interest to use of the briquettes and pellets in the future. According to (García-Maroto et al. 2015) knowledge about the pellet plays a role in order to using it. Research from Norway showed that respondents with knowledge in pellets are more agree to use it (Tapaninen 2008).

6 Conclusion

Solid biofuels made from agriculture waste become a prospective environmentally friendly source of energy that has many advantages comparing to fossil fuels. Tajikistan has many well-developed regions of agriculture, which not only play a crucial economic role at the same time also, generate wastes (biomass) collected each year in large quantities. This dissertation has focused using agricultural waste (cotton bush and apricot tree branches) as renewable source of energy in Tajikistan. According the data from laboratory research and settled hypothesis following conclusions were made.

The energy potential of abundant agricultural waste, in the processing of cotton bushes and apricot tree branches as briquettes and pellets, seems to be one of the most effective energy and environmental solutions for Tajikistan, cotton bush and apricot trees as biomass in Tajikistan has big prospective of using them as renewable source of energy.

Based on results the first hypothesis (***Energy potential/energy yield of residual biomass from apricot tree branches is smaller than energy potential of cotton bushes in Tajikistan.***) has been confirmed. Even though the apricot tree branches considered as woody biomass and has higher calorific value due less availability of biomass in the field (harvested area) energy potential of apricot tree branches in Tajikistan is smaller than cotton bush.

Also, the result showed that second hypothesis (***Overall quality of solid biofuels made of selected biomass materials fulfills the standard requirements (BS EN ISO 17225 - 1 2014)***) as well confirmed. Produced biofuels (briquettes and pellets) from cotton bush and apricot tree branches corresponds to presented standards. Briquettes and pellets from cotton bush fully corresponds to requirement for non-wooden biofuels. Due to higher ash content, higher nitrogen and slightly lower $NCV_{a.r.}$ biofuels from cotton bush did not responds to wooden biofuels. The content of other elements and heavy metals within the limits. Mechanical durability of briquettes and pellets from the cotton stalks equal to A1 class wooden briquettes and pellets. Biofuels from apricot tree branches have proved physical, chemical and mechanical properties which corresponds to presented requirements and fulfill the A1 class wooden solid biofuels, beside mechanical durability of the pellet did not correspond to A1 class, but it can be improve during the processing. As well good quality in comparison with other solid biofuels made from different agricultural waste biomass.

Hypothesis three (***Household income influence the intention to use biofuels in form of briquettes and pellets in the future***) result from Fisher exact test and the binary probit model shows that households with higher income are less interested to use the briquettes and pellets in the future.

Hypothesis four (***Scarcity of energy influence the intention to use biofuels in form of briquettes and pellets in the future***) result is from Fisher exact and binary probit model visible that respondents experiencing the energy scarcity are willing to use the briquettes and pellets in the future.

Overall, solid biofuels from cotton bush and apricot tree branches has positive outcomes and establishment of briquettes and pellets production will have a positive impact in energy stability especially in rural area. As there is no industrial large – capacity pellet or briquette manufacturer in the country yet, a development of local small – scale production is recommended especially in north part of Tajikistan.

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8 Annex

List of annexes

Annex 1 **Questionnaire survey**

Part I – demographic characteristics

Age of household head

Gender of household head

Male мард
Female зан

Highest level of completed schooling of household head

Illiterate
Secondary school
Primary school
College / University

Area of residency___________

Do you live in

Rural area

Urban area

How many people is living in your households?

Your family income per month

0 – 500 somoni
501 – 1000 somoni
1001 – 1500 somoni
1501 – 2000 somoni
2001 – 2500 somoni
More than 2501 somoni

Part II – energy use

What kind of energy do you use for heating?

Electricity
Wood
Coal
Gas
Briquettes
Pellets
Other, please mention _________

Do you have your own source of energy?

Yes
No

If yes, what kind of energy? Please mention

How often do you use these kinds of energy during the heating period?

	very often	Often	Sometimes	Rarely	Never
Electricity					
Wood					
Coal					
Gas					
Briquettes					
Pellets					
Other					

What type of heating system do you use in your house?

Electricity type of heating

Gas type of heating
Wood and coal type of heating
Other, please mention ________

Where do you purchase following sources of energy?

	Local market	From farmers	Central market	Private business	Other
Wood					
Coal					
Gas					
Briquettes					
Pellets					
Other					

How much heating material (coal, wood, gas) do you buy for heating season?

0-500kg
501-1000kg
1001-1500kg
1501-2000kg
More than 2001 kg

How much money do you spend for your heating during the heating season?

0-500 somoni
501-700 somoni
701-1000 somoni
1001-1500 somoni
1501- 2000 somoni
More than 2001 somoni

Is there a period of heating materials scarcity?

Yes
No

If yes, please mention the kind of energy source and period

Part III – Briquettes and pellets

Do you know what briquettes are?

Yes
No

Would you like to use briquettes in the future?

Yes
No

Do you know what pellets are?

Yes
No

Would you like to use pellets in the future?

Yes
No

Do you use cotton bushes?

Yes
No

If yes for which purpose?

Heating
Cooking
Briquettes and pellets
Other __________

Do you use apricot tree branches (after pruning)?

Yes
No

If yes for which purpose?

Heating
Cooking
Briquettes and pellets
Other __________

Annex 2 **Confirmation and transportation letter of biomass (cotton bush)**

Муассисаи Давлатии «Точик НИИГиМ»
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CONFIRMATION and TRANSPORTATION LETTER

Based on the request from the Czech University of Life Sciences, Faculty of Tropical AgriSciences and cooperation in the framework of the doctoral research conducted by Dipl.-Ing. Sayfullo Akhmedov, we have prepared the materials for laboratory tests in the Czech Republic.

The items for avia transportation are as follow:

- One bag of **residual cotton biomass** (i.e. post-harvest trash) with the total weight of 10.85 kg. The biomass was collected manually from three 4x4 m plots that were randomly selected within one hectare of plantation.

Representative samples for both materials were gathered from the harvested biomass according to the standard sampling methodology EN 14778:2011.

The prepared materials are properly packed, they are not dangerous and are legal for transportation.

16.12.2015

Director, Ph.D.
candidate of agriculture science
Gaybullo Akhmedov

Annex 3 **Confirmation and transportation letter of biomass (apricot branches)**

ҶУМҲУРИИ ТОҶИКИСТОН
АКАДЕМИЯИ ИЛМҲОИ
КИШОВАРЗИИ ТОҶИКИСТОН

ФИЛИАЛИ ИНСТИТУТИ
БОҒПАРВАРИЮ
САБЗАВОТКОРӢ ДАР
ВИЛОЯТИ СУҒД НОҲИЯИ
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тел: 928881430

02.02.2017

CONFIRMATION and TRANSPORTATION LETTER

Based on the request from the Czech University of Life Sciences, Faculty of Tropical AgriSciences and cooperation in the framework of the doctoral research conducted by Dipl.-Ing. Sayfullo Akhmedov, we have prepared the materials for laboratory tests in the Czech Republic.

The items for avia transportation are as follow:

- One bag of **apricot biomass after pruning** (branches) with the total weight of 10.7 kg. The biomass was collected manually from ten randomly selected trees spread throughout one hectare of plantation.

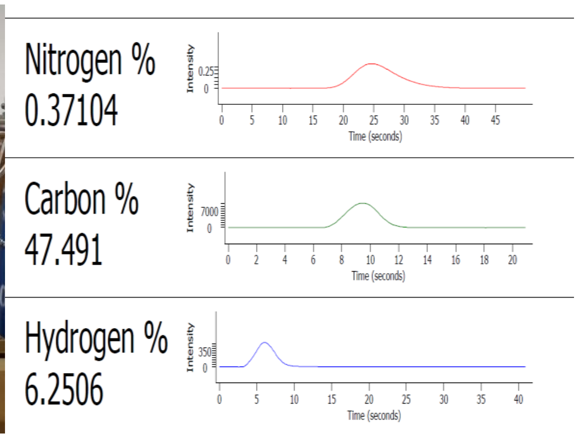
Representative samples for both materials were gathered from the harvested biomass according to the standard sampling methodology EN 14778:2011.

The prepared materials are properly packed, they are not dangerous and are legal for transportation.

Director, Phd
candidate of agriculture science

Boboev M.

Annex 4 **Photo from the laboratory during the experiments**



Annex 5 **List of Author's publications**

Article with IF index

AKHMEDOV, S. – IVANOVA, T. – KREPL, V. – ABDULLOEVA, S. – MUNTEAN, A. Contribution to the energy situation in Tajikistan by using residual apricot branches after pruning as an alternative fuel. *Energies*, 2019 vol. 12, issue 16, p. 3169, ISSN 1996-1073

Article with SJR index

AKHMEDOV, S. – IVANOVA, T. – KREPL, V. – MUNTEAN, A. Research on solid biofuels from cotton waste biomass – alternative for Tajikistan's energy sector development. *Agronomy Research,* 2017, roč. 15, č. 5, s. 1846-1855. ISSN: 1406-894X.

AKHMEDOV, S. – IVANOVA, T. – KREPL, V. Podtyp: Příspěvek ve sborníku (mimo kategorie RIV); Development of Tajikistan's energy sector by using of agricultural waste biomass. 2015, Abstract in the Book of Abstracts from the 2nd International TBCC 2015 Tropical Biodiversity Conservation Conference. pp. 10-11. Conference poster.