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UNDP
SUSTAINABLE
DEVELOPMENT OF
BIOMASS
FOR HEATING IN
ARMENIA

SUSTAINABLE DEVELOPMENT OF BIOMASS FOR HEATING IN ARMENIA

Yerevan 2020

The guidelines was developed under the auspices of the Ministry of Environment of the Republic of Armenia by UNDP and GEF financial support within the framework of the "Mainstreaming Sustainable Land and Forest Management in the Mountainous Landscapes of Northeastern Armenia" project.

The study was conducted by a joint Moldovan-Armenian team led by Nikolae Zakharia

This study aims to present the whole chain of development potential of the biofuel market in the Republic of Armenia: the potential of different types of biofuels, technological solutions for their processing and biofuel market development mechanisms and solutions. The second part of the study is dedicated to the detailed presentation of the roadmap for the development of the biofuel market. The results of this study are intended for a wide range of professionals in the fields of agriculture, forestry, environment, engineering, economics and related fields, as well as students and researchers.

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1 INTRODUCTION

Burning fossil fuels and deforestation contribute significantly to anthropogenic climate change is generally acknowledged. Lack of will and/or incentives for a global shift towards alternative sources lead to unavoidable and unchangeable outcomes that are affecting the environment of many countries around the world.

Renewable energy supplies around one-fifth of the final energy consumption worldwide, counting traditional biomass, large hydropower, and "new" renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels)[1]. Latest predictions indicate that one third of the overall global energy mix is likely to be powered by biomass, by 2050. As one of the most available alternative sources of energy, it has quickly become a key element of the world renewable energy mix, which has the quickest-growing proportion of the world's heating power. Because it is readily available in rural and urban areas of almost all countries, biomass-based industries can foster rural development, provide employment opportunities and promote biomass re-growth through sustainable land management practices.

The use of thermochemical conversion technologies could play a key role in reducing dependency on fossil fuels as well as reducing illegal cuttings of trees. Therefore, increased use of biomass-based fuels would contribute to environmental conservation, generating new jobs, sustainable growth and improving health in rural areas.

There are significant opportunities for reducing greenhouse gas emissions by using biomass energy systems in Armenia. Its potential to replace fossil fuels in energy production is not explored at all. The timid attempts to understand the need and importance of the local biomass market development have been baffled by obvious economic reasons.

1.1 COUNTRY BACKGROUND

Armenia has a population of over 3,262 thousand people, including 2,088 thousand people (64%) living in urban areas and 1,174 thousand people (36%) living in rural communities.

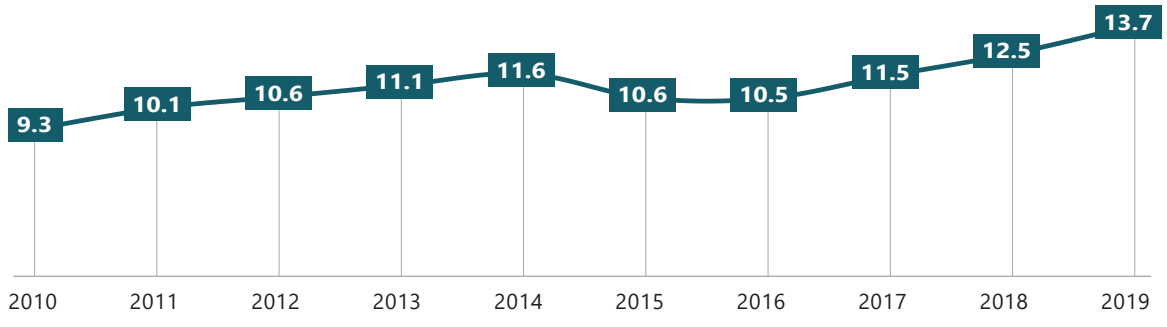


*Figure 1 **Armenia GDP at market prices, absolute value in billion USD***

In 2019 RA GDP at market prices reached USD 13.7 billion registering 7.6% growth.

1 Source: https://www.bioenergyconsult.com/a-glance-at-biomass-energy/

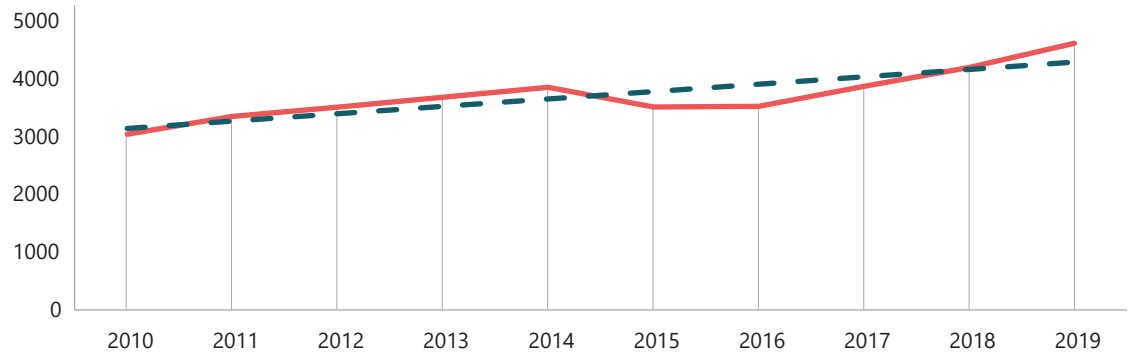


Figure 2 *Armenia GDP per capita, USD[1]*

In its turn GDP per capita reached USD 4615.7, which is higher than that of 2018 by 10%, which was accompanied by a decrease in population by 0.22% for the same period.

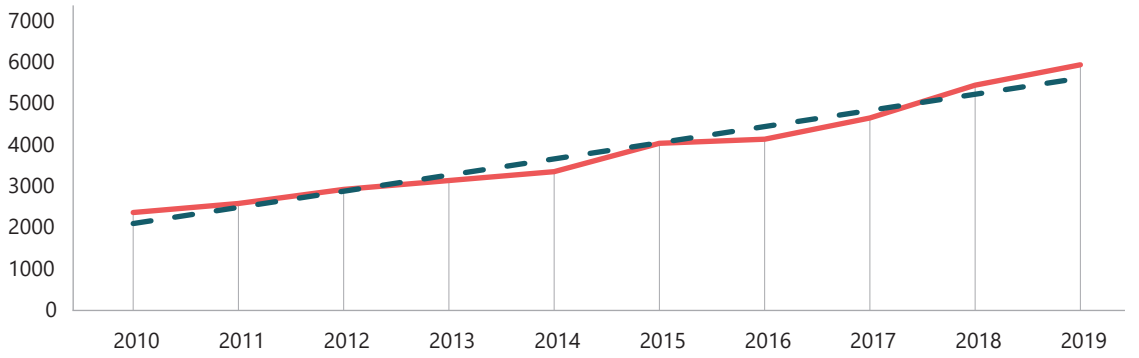


Figure 3 *Armenia GDP per capita, USD[2]*

The chart shows that in recent years, GDP per capita has been growing steadily, in particular due to stable growth of monthly nominal wages. Thus, in 2019, the average monthly nominal wages in Armenia reached 488.8 US dollars, which is 5.8% more than in 2018.

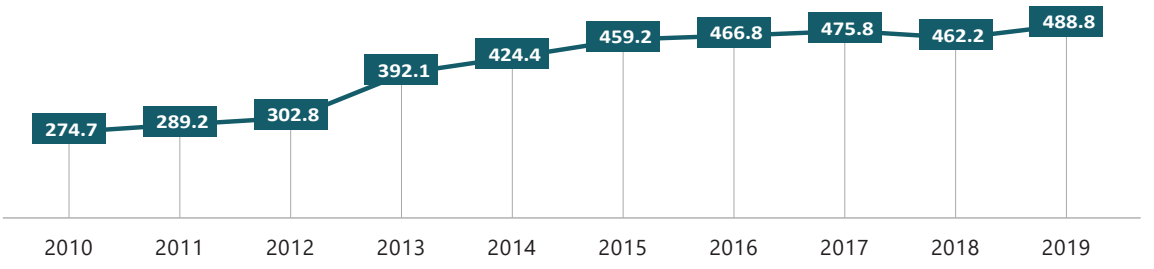


Figure 4 Average monthly nominal wages in Armenia, USD

1 https://armstat.am/en/?nid=12&id=01001

2 https://armstat.am/en/?nid=12&id=08001&submit=Search (** The indicator of 2019 is preliminary. *** Since 2013 the indicator calculated by the RA Law "On Income Tax", according to which "employer's statutory social security contribution" is also included in the "employees' remuneration and other payments equal to it". With the aim to provide comparability of indicators for 2012-2013, the indicators for 2012 were re-calculated using the method of applying the calculated (conditional) rates of employer's statutory social security contribution.
The indicator of average monthly nominal wages/salaries for 2012-2017 includes data on remuneration of servicemen as well. According to above mentioned clarifications the revised indicator for 2012 has comprised 140739 drams.)

The country is characterized by sustainable energy supply and full electrification. All households have reliable access to electricity which is supplied by distribution network. Armenia has limited fossil fuel and coal reserves, and no confirmed oil or natural gas reserves. The energy system of the country is highly dependent on electricity generation. Currently, Armenia can meet only 35 per cent of the current demand for energy with its domestic resources. Therefore, the development of renewable energy resources is of critical importance for the country. Due to low incomes and high poverty rate of the population, the demand for thermal energy for heating and hot water is limited. This is considered one of the main reasons why logwood remains primary heat energy source for 12-15% of the total population of Armenia for some time. Forest biomass, however, is not considered a promising source of biofuels in Armenia, given the fact that forest lands occupy only 11% of the country area. As a response to this challenge, one of the priority actions for climate change adaptation established by the authorities is implementing the strengthening of the conservation regime of forest ecosystems through reforestation and establishment of new forests. The plan is to increase the forest cover of the country to 20.1% by 2050.

Armenia has significant indigenous renewable energy resources, and an educated workforce with extensive scientific and engineering expertise. Furthermore, the Government has taken proactive steps in recent years to craft laws and regulations designed to reform the power sector to enable private sector involvement in renewable energy technology development. However, Armenia's renewable energy sector faces a number of important barriers to its deployment, primarily related to the availability of financing, the regulatory framework for renewable energy, the high cost of renewable energy technologies and public awareness of the potential benefits of renewable energy technologies.

1.2 BIOMASS SECTOR DEVELOPMENT CONSTRAINTS IN ARMENIA

The major challenge is to manage, transport, store and burn the biomass. Densification, a method that generates either liquid or solid fuel with denser and more consistent properties than the raw biomass, may resolve these issues.

Today, biomass energy continues to be the main source of energy in many developing countries, particularly in its traditional forms, providing on average 35 per cent of the energy needs of three-quarters of the world's population. This rises to between 60 and 90 per cent in the poorest developing countries. However, modern biomass energy applications are increasing rapidly both in the industrial and developing countries, so that they now account for 20–25 per cent of total biomass energy use. For example, the United States obtains about 4 per cent and Finland and Sweden 20 per cent of their primary energy from biomass.

The reasons behind the need to develop the biomass sector in Armenia is multi-tiered. One of the first reasons is the use of wood for energy that is illegally cut. A household survey conducted in 2017, indicated a 72% share of rural households using firewood as primary heating source. Despite official information regarding annual permissible felling allowed in forestry areas of Armenia by "Hayantar", SNCO, the research by the State Forest Monitoring Center SNCO, claimed the demand for firewood in Armenia being around 709,851 cubic meters during the heating season of 2010-2011, 977,011 cubic meters in 2013-2014:, and 842,477 cubic meters in 2017-2018 (annual report, 2017). On the other hand, the Energy Consumption Survey on households for heating purposes conducted by the Center for Economic Development Research, revealed about **2 million cubic meters** of firewood consumed each year during the same period, including 1.5 million cubic meters in rural communities, 0.07 million cubic meter in Yerevan and 0.5 million cubic meters in other cities of Armenia. Also, a steady increase of the deforested areas is observed in Armenia with 1,558 hectares in 2015, up to 2010 hectares in 2018.

The fuel poverty is another considerable reason to develop biomass sector. Attractive prices for logwood as well as low incomes in rural areas are the reasons why most of the population in the villages of Armenia is "addicted" to wood as the main source of energy. In addition, most of the used stoves in the above-mentioned regions are with poor or no track of efficiency. Therefore, when thinking about the preservation and sustainable increase of the country forested areas trough substituting the wood used for energy purposes, it makes great sense to look into locally available resources, that can partially or totally meet the demand. The option deserving attention is exploiting the agricultural biomass residues, which are currently burnt in the field. Those can be transformed into suitable fuel to be

used in the existing rural stoves. The latter could be gradually improved to fit both briquettes and pellets, providing high efficiency of burning fuel.

In terms of biomass potential, there are exceeding quantities of agricultural biomass residues available on the fields that can be transformed into fuel. The biggest potential is held by cereals' straw, corn stalks, artichoke, grass, small branches, etc. There is also high potential for special purpose annual and perennial energy crops such as miscanthus, canary reed, sagebrush, poplar, willow, paulownia, etc. These can be introduced as main agricultural crops or as perennial plantations in lands unsuitable for other agricultural areas (swampy, saline, severely degraded, rocky and other soils).

1.3 AIM AND SCOPE OF THE REPORT

This report aims at providing an overview of the opportunities for a sustainable development of the biomass sector in Armenia. A detailed assessment of its potential was conducted per region to understand the geographic distribution of the resources. Because Armenia has a truly diverse landscape, the resources are distributed unevenly, which requires individual solutions to develop the sector. The available official figures on biomass potential are, however, not always trustworthy, therefore the report cannot claim an accurate inventory of the overall biomass available today in the country. The major goal was to identify the potential of biomass required to replace the amount of logwood which is currently used as primary source of heating and cooking in the rural areas of the country. Also, the report aims at presenting the technologies required to transform the available potential into fuel as well as means of using it for energy purposes within the rural households. All proposed solutions are linked to some available experience within the country or the region and provide recommendations on sustainable transformation of biomass into energy.

This analytical report serves as a background for the recommendations listed in the "Roadmap to sustainable development of biomass sector in Armenia" which provides straightforward advice and suggestions about the best suited model of converting biomass into energy in Armenia.

The feasibility and the way forward to biomass market development was assessed according to legal, economic, environmental and social results and implications.

- **Assessment of the regulatory framework**

The legal framework assessment has been done by analyzing existing regulatory acts having potential implications for the development of the biomass processing field

- **Assessment of biomass economic potential**

The potential of biomass has been estimated based on the official data. Per region estimations have been done to emphasize the differences in potential these regions have. Estimations regarding the energy embedded in the existing biomass have been done to approximate the logwood which can be replaced by it.

Estimations regarding the energy potential of the residues were assumed based on generally accepted indicators, as follows:

- **Evaluation of existing heating solutions on biomass**

Previous studies and research have been used to identify the currently used logwood heating solutions. The findings have been compared to the European trends to identify the level of current development as well as the potential for improvement.

- **Assessment of the biomass fuel production and its sustainability**

Official sources as well as public trading information has been used to identify the overall production capacity of biomass fuel in Armenia. European experience and equipment have been presented to offer a wide perspective which can be achieved in case the full biomass potential of the country is harnessed.

Quality standards as well as potential capacities for certifying the quality of local biomass fuel has been assessed.

- **Assessment of social and environmental implications**

This has been done by calculating the amount saved fuelwood that would have been spent to heat the houses.

1.4 METHODOLOGY

Crop	Biomass residue	The coefficient of output of biological waste generated in relation to the amount of harvest *t/t of grain, t/ha (vineyards, orchards, forests)*	Reference Heat Capacity, MJ/kg	Market availability factor, %
Winter Wheat	Straw	1.5	15	25
Winter Barley	Straw	1.3	15	25
Winter rye	Straw	1.5	15	25
Spring wheat	Straw	1.3	15	25
Spring barley	Straw	1.2	15	25
Spring rye	Straw	1.2	15	25
Oats	Straw	1.4	15	25
Spelt	Straw	1.5	15	25
Maize for grain	Stalk	1.3	16.8	65
Sunflower	Stalk	1.4	16.2	65
Fruit trees	Branches	1.2	15	95
Vine	Branches	0.8	15	97

Table 1 *Biomass residues coefficients*

REGULATORY **FRAMEWORK**

2 REGULATORY FRAMEWORK

Sustainable development and promotion of green economy in Armenia are defined as priorities for the country's development , which include the rational use of natural resources, the development of resource and energy saving in different areas of the economy, as well as the introduction of new and effective technologies and management mechanisms. In the context of sustainable development, one of the most important components of the policy pursued in the country is the protection of forest ecosystems and the cessation of previously massive deforestation, which has led to significant changes in the firewood market: lower firewood supply, lower quality firewood, increase in the price of solid energy, etc.

According to various studies and figures presented by official sources, in Armenia still, especially in rural communities, the majority of the population uses solid fuels for heating apartments - wood, manure, tart, etc. This is especially evident in non-gasified rural communities, although a significant part of the population in gasified communities also cannot afford to use natural gas for heating due to their social status.

However, it can be stated that the legal framework regulating the production and application of VEA technologies in Armenia is developing year by year, in terms of biomass energy it is still at a very early stage of development and is just beginning to take shape.

In the normative legal field regulating the production and consumption of biofuel in Armenia, the following main directions that need to be regulated can be distinguished:

1. Organizational and legal regulations (expediency of the legal form of individuals or companies producing raw materials or biofuels, normalization of relations between communities, farmers and entrepreneurs, microgeneration in the field of bioenergy, national standards for production and use of solid biofuels, quality control mechanism).
2. Raw materials and resource regulations (specification of volumes and forms of forest waste use, formation of environment to prevent destruction and promote the use of agricultural waste, regulation of food and non-food industry residues, regulation of energy crops and perennial energy plantations, etc.)
3. Environmental regulations (solid waste management, maintenance of air basin cleanliness, reduction of greenhouse gas emissions, etc.);
4. Promotion of relations with the scientific-educational sphere (increasing the interest of specialists and institutions in the field of science and technology, development of new technologies, training, retraining, etc.),
5. Economic and market regulations (promotion of production of various biofuel products, state support for the development of the sector, strengthening of cooperation with donor organizations, easing of tax policy, customs privileges, etc.).

Regarding the organizational and legal regulations, it should be noted that the policy and legislation related to the field of solid biofuel production in the Republic of Armenia are included in the whole sector of renewable energy, where biomass and biofuel subsectors are separated only in rare cases when their characteristics play a legislative role. in regulations, for example, in the case of setting a sales tariff for the production of electricity through biomass.

The main responsible body for the development of legislation and sectoral policy on renewable energy issues in Armenia is the Ministry of Territorial Administration and Infrastructure of the Republic of Armenia, which is responsible for the management and control of this sector in the country. The RA Ministries of Environment, Economy and Emergency Situations are also directly or indirectly related to the development of biofuel production.

Armenia Renewable Resources and Energy Efficiency Fund, which was established by the Government of the Republic of Armenia and has been operating since 2006, is heavily involved in renewable energy research, policy development, legislative improvement and funding in Armenia. It is a non-profit state-owned renewable resources and energy efficiency development environment organization that incorporates the best sustainable energy practices to ensure Armenia's energy security and independence, and to promote economic growth.

During the last 15 years, to reform the energy sector, the RA government has initiated quite serious changes in the legislative field. The

legislation on renewable energy development has been formed in the country, which has provided certain positive changes in that sphere, but it has not brought significant positive changes in the biomass energy subsector.

Among the main legislative and strategic documents presenting and regulating Armenia's renewable energy policy are

- the RA Law "On Energy" N.ՀՕ-148 of 07.03.2001,
- RA Law "On Energy Saving and Renewable Energy" N ՀՕ-122-Ն of 09.11.2004,
- the "National Program on Energy Saving and Renewable Energy (2007),
- Order of the President of the Republic of Armenia "On approving the concept of ensuring the energy security of the Republic of Armenia" (2013) ,
- "Program of Energy Security of the Republic of Armenia for the years 2014-2020" (2014) ,
- "Strategic document for the long-term development of the RA energy system (until 2036)" (2015), etc.

The purpose of the RA Law "On Energy Saving and Renewable Energy" N ՀՕ-122-Ն of 09.11.2004is to define the principles of the state policy on the implementation of energy saving and the development of renewable energy and the mechanisms of their implementation, which are aimed at:

- Strengthening the economic and energy independence of the Republic of Armenia,
- Increasing the level of economic and energy security of the Republic of Armenia, the reliability of the energy system,
- Creation of new products and services promoting energy saving and renewable energy development;
- Reducing the man-made impact on the environment and human health.

The measures presented in the strategic document "Strategic document for the long-term development of the RA energy system (until 2036)" are conventionally divided into two periods: medium-term (until 2025) and long-term (until 2036). As a result of the project, it is planned to change the structure of energy consumption in Armenia, bringing the share of renewable energy in the structure of energy production to 40%.

Despite the existence of the relevant legislative framework and strategic documents, renewable energy in Armenia has not yet reached the desired level and volume of development, and today there is a need to create a more favorable environment for the development of this sector in the country.

On 7 February 2018, as a result of making amendments and additions to

- the RA Law "On Energy" N.ՀՕ-148 of 07.03.2001,
- Law of the Republic of Armenia "On Licensing" N ՀՕ-101-Ն of 07.02.2018,
- Law of the Republic of Armenia "On State Duty" N ՀՕ-102-Ն of 07.02.2018by the RA National Assembly, the process of liberalization of the RA electricity market started.

At the same time, according to the legislation of the Republic of Armenia, private electricity producers can sell the electricity they produce only to the electricity distribution company and do not have the right to sell it directly to other potential consumers.

In order to promote the receipt of energy from the biomass, the RA Public Services Regulatory Commission on 27.05.2020 adopted the decision No. 176-N, according to which: "The tariff for electricity supplied from power plants producing electricity from the biological mass is 43,811 drams / kWh without value added tax." For comparison, let us mention that according to the same decision, the selling price of electricity produced by solar photovoltaic power stations is 24,323 drams / kWh without VAT. In other words, the electricity produced from the biological mass is bought by the network at a price 1.8 times higher than the electricity produced by the solar power plants. The mentioned tariffs will be in force in Armenia from 01.07.2020 to 01.07.2021.

But business initiatives to generate electricity from biomass in Armenia have not yet received sufficient impetus and the development process in this area is very slow. As of 01.04.2020, the only company in Armenia that produces electricity from biomass is Lusakert Biogas Plant CJSC, which operates near a poultry factory and has the opportunity to process 200-250 tons of liquid poultry manure per day. It has an installed capacity of 835 kW, the actual average annual useful delivery of electricity is 2.32 million kWh, but it operated in 2008-2014, currently not operational, although the company has already initiated a project to restart the biogas plant.

In order to promote the development of

bioenergy in Armenia, there is a need to form a favorable legislative framework and appropriate sectoral policy. This implies the development and implementation of appropriate strategies by government agencies to promote the widespread introduction of biomass collection, use and production of biomass fuel.

Biomass energy in Armenia today needs economic promotion, commercialization and deployment on a large scale, for which it is necessary to stimulate the production of biofuels by individuals and companies, regulate relations between communities, farmers and businesses, allow micro-energy and free trade in the field of bioenergy, both in terms of electricity and thermal energy, establish national standards for the production and use of solid biofuels, and establish national quality control mechanisms for biofuels.

From the point of view of raw materials and resource regulations, the development of biomass energy in Armenia is directly related to the policy pursued in the fields of forests, agriculture and waste management in the country and the existing legislative framework.

At present, the potentials for biogas and bioethanol production in Armenia are assessed, and the developments related to the promotion of solid biofuels are mainly related to UNDP-funded programs and studies in Armenia. Although, recently the Government of the Republic of Armenia speaks more often about the need to develop this direction.

According to the website of the Ministry of Territorial Administration and Infrastructure, the potential for biogas production in Armenia is estimated at 135 million cubic meters per year. In this field, starting from 2002, in cooperation with the Japanese "Shimizu" corporation, the program "Use of biogas and production of electricity in the Nubarashen solid waste landfill" is being implemented in Yerevan. It is estimated that at least 56,000 tons of carbon dioxide-equivalent emissions are expected to be reduced annually, but unfortunately, due to disagreements over the terms of cooperation, the biomass generated from the landfill has not been implemented so far, but is simply burned in the open air, without its energy potential being used.

Assessing the prospects for bioethanol production and development potential in Armenia has shown that the long-term bioethanol production potential in Armenia is about 30,000 tons / year, which is about 10% of the average annual volume of gasoline consumed in Armenia.

One of the most important directions in the production of biofuels is forestry and especially the regulation of the use of forest waste/ remains (**թափուկ**՝ անտառային հողի վրա ընկած, մահացած ծառերի մասեր կամ բներ.) for that purpose.

The main legal and strategic documents of Armenia related to the forest sector are

- the RA Forest Code N ՀՕ-211-Ն of 24.10.2005,
- the RA National Forest Program,
- the international agreements ratified by the RA related to the forest sector, etc.
- The RA Civil Code N ՀՕ-239 of 05.05.1998,
- the RA Administrative Offenses Code of 06.12.1985,
- the RA Land Code N ՀՕ-185 of 02.05.2001,
- the RA Law "On Specially Protected Areas of Nature" N ՀՕ-211-Ն of 27.11.2006,
- the RA Law "On Tariffs for Compensation of Damage Caused to Fauna and Flora as a Result of Environmental Violations" N ՀՕ-88-Ն of 03.05.2005,
- RA Law "On Environmental and Nature Use Fees" N ՀՕ-245-Ն of 20.12.2006,
- RA Law "On Environmental Impact Assessments and Expertise" N ՀՕ-110-Ն of 21.06.2014,
- RA Law "On Environmental Control" N ՀՕ-82-Ն of 11.04.2005etc. are also related to this sphere.

The structures directly involved in forest management in Armenia are: "Hayantar" SNCO under Forest Committee in the structure of the Ministry of Environment, " Hydrometeorology and monitoring center SNCO in the structure of the Ministry of Environment of RA, Inspectorate for Nature Protection and Mineral Resources under the Government of Republic of Armenia .

The study of the legal and strategic documents of the RA forest sector shows that the issue of using forest waste for the production of biofuel in Armenia is not regulated and there is no mention of it. The only document that refers to the procurement of non-productive firewood for families living in the immediate vicinity of forests is the decision of the Government of the Republic of Armenia No. 1535-N of 27.10.2011, which establishes a privilege for nature use fees.

Waste procurement is carried out by the Government of the Republic of Armenia of

October 27, 2011 "On establishing a privilege on the fee for nature use for procurement of non-productive (non-industrial) firewood used by families living in forested settlements of the Republic of Armenia", as well as the Republic of Armenia N 296-A of the Minister of Agriculture of November 29, 2011 and N 253-A of the Minister of Nature Protection of the Republic of Armenia of November 29, 2011 "On approving the procedure for procurement and release of free firewood for non-productive purposes" and Minister of Agriculture of the Republic of Armenia 2011 November 29, N 297-A, Minister of Nature Protection of the Republic of Armenia November 29, 2011 N 254-A and Minister of Territorial Administration of the Republic of Armenia November 14, 2011 N 144-A "Received a privilege to purchase free firewood for non-production purposes According to the joint order on approving the list of settlements in the immediate vicinity of forests.

Today, taking into account the environmental impact on forests, there is an urgent need to regulate the use of forest waste suitable for biofuel production in Armenia, clarifying their reasonable volumes and forms, which can become an important factor in promoting solid biofuel production in forest communities.

The next most important source of raw materials for the production of biofuels is the biological residues generated in the agri-food complex, as well as solid waste generated in industrial sector and household.

The main legal documents regulating the sphere of waste management in the Republic of Armenia are:

- RA Law "On Wastes" N ՀՕ-159-Ն of 24.11.2004,

the RA Law "On Collection of Garbage and Sanitation" N ՀՕ-237-Ն of 23.06.2011 and a number of RA Government decisions on waste generation standards determination of limits, registration, passportization , state cadaster, etc.

Among the legal documents indirectly related to the sphere, there are the following:

- the RA Administrative Offenses Code of 06.12.1985,
- the RA Law "On Local Self-Governance" N ՀՕ-337 of 07.05.2002and the RA Law "On Condominiums" N ՀՕ-333 of 07.05.2002,
- the RA Minister of Health 22.12.2009. Order No. 25-N. Armenia has also signed a number of international agreements, which to some extent relate to waste management issues, but they mainly relate to the management of special hazardous waste.
- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
- Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade
- Stockholm Convention on Persistent Organic Pollutants
- Minamata Convention on Mercury

The RA Law on Wastes (2004) regulates the use of waste generated during production and consumption, defines the powers of state and local self-government bodies: waste collection, transportation, storage, processing, utilization, disposal, volume reduction and other related matters, as well as the legal and economic basis for preventing adverse effects on human health and the environment.

Article 19 of the Law is defining the rights of legal entities and private entrepreneurs in the field of waste management. In the field of waste management, legal entities and private entrepreneurs have the right to: c) of being privileged who will organize waste processing, in the manner and cases prescribed by the law of the Republic of Armenia and other legal acts;

Unfortunately, further procedure for getting this privilege does not developed and in fact this opportunity is not used.

In the meantime, according to the RA Law on Environmental impact assessment and expertise some operations with the hazardous waste are the subject of environmental impact assessment.

According to Article 18 above mentioned law strategic paper, which have to be assessed also will include information on waste. Particularly

- the physical characteristics of the activities envisaged within the framework of the founding document and the description of the possible risks of resource requirements,
- materials used,
- technological processes,
- emissions,
- leaks,
- wastes,
- production

- landfills,
- physical impacts and emergencies

The RA Law on Garbage Collection and Sanitation (2011), which regulates the relations related to garbage collection and sanitation in the territory of the Republic of Armenia, defines the principles of organizing that process, garbage collection fees, rates, payers, their rights and responsibilities, payment procedure, the procedure for exercising the powers of the local self-government bodies in this area for non-payment of fees.

The current legal framework does not regulate the actual management of industrial and household waste, and agricultural and forest waste is not mentioned in any law in Armenia.

Among the legal documents indirectly related to the field, there are two articles in the RA Code on Administrative Offenses, which refer to incineration of production and consumption wastes in the natural environment and in settlements (Article 85.1.) and to incineration crop residues, areas with plant residues and dried vegetation, pasture and grassland vegetation, vegetation in the lands of forest and specially protected areas (Article 85.1). In case of these violations, fines are envisaged for both citizens and officials. However, it should be noted that these articles of the law are rarely used in practice in Armenia, as the burning of plant residues, both for citizens and representatives of local self-government authorities, is considered a natural phenomenon and if there are no complaints, they are usually not punished. As crop residues are more likely to form and be burnt in rural communities, it should be borne in mind that this is such a common practice that villagers do not even complain to each other, and after complaining, it is usually necessary to prove who burned it, which is quite difficult if there is no factual evidence. Therefore, as a mechanism to ensure the implementation of this provision of the law, it should be amended, in particular, to impose a fine not on the burner, which is very difficult to prove, but to impose a fine on the owner of the area, which will help the owner be interested in Quickly removing the biological waste from the property. This change can also be useful in terms of stimulating the production of solid biofuels in the country, as it will increase the motivation of landowners in the process of collecting raw materials.

The RA draft law on "Community Waste Management" is currently in circulation , the aim is to establish a legal framework for the implementation of measures in the field of community waste management, which will contribute to the prevention and increase of community waste generation, as well as environmentally safe treatment (the latter includes community waste recycling and separation of secondary raw materials, energy recovery and safe disposal). However, even this draft law does not regulate agricultural, forest and household biological wastes.

In the Republic of Armenia, in the field of waste management, there are still no legal and strategic documents, which set out the general principles of agricultural, forest and household biological waste management, the policy pursued in the field of their recycling and the limits and ways of their use in biofuel production. The legislative field regulating this sphere in the country is still being formed. There is a need in Armenia today to regulate the management of agricultural, forest and household biological wastes, to prevent their destruction by aimless incineration and to promote the formation of an environment that promotes their use in the field of solid biofuel production.

From the point of view of raw material and resource regulations, one of the important directions contributing to the development of solid biofuel production in Armenia is the legislative regulation of the introduction of energy crops and the establishment of perennial energy plantations, which remains open so far.

From the point of view of environmental regulations, the main legal acts regulating the development of biomass energy are:

- the RA Land and Water Codes, the RA Law on Atmospheric Air Protection,
- the RA Law on Fire Safety
- other RA laws regulating these three spheres and normative-legal documents, as well as international agreements and protocols.

Almost all national and international legal and strategic documents in the field of environment and emergency situations in Armenia are indirectly related to this issue, but the most important of them are the UN Framework Convention on Climate Change, the Kyoto and Paris Agreements, the Convention on Biodiversity, the Convention for the Suppression of Desertification, etc.

The nature of the biofuel production process implies a positive impact on the environment not only from the proper management of biological waste but also from the reduction of carbon

dioxide emissions. Solid biofuels are considered to be climate-neutral energy sources, as their combustion releases just as much carbon dioxide into the atmosphere as it does during plant growth. Due to this, organizational measures to reduce carbon dioxide emissions have an indirect regulatory effect on the production of biofuels.

The promotion of relations with the scientific-educational sphere presupposes reforms of the legislative field, which will increase the interest of scientific-technical specialists and institutions in the production of solid biofuels, will stimulate the development of new technologies in that sphere, training and retraining of personnel. Today in Armenia there is a demand for specialists in production organization and development in the fields of bioenergy and biofuel production.

Economic and market regulations may include the promotion of the production of various biofuels through state support programs, the promotion of cooperation with donor organizations in this field, the establishment of tax benefits for biofuel producers, the establishment of customs privileges for the import of biofuel equipment or many other means.

ASSESSMENT OF ARMENIA **BIOMASS** POTENTIAL

3 ASSESSMENT OF ARMENIA BIOMASS POTENTIAL

Around the world, biomass is the main contributor to renewable energy. Of all energy sources, biomass is the third largest energy resource in the world and it is also the most dominant source of cooking and heating energy for three-quarters of all people in developing countries[1]. According to a recent IEA Bioenergy report, renewables accounted for a share of 13% of total energy consumption in 2019 (IEA Bioenergy, 2018). The following classification of biomass feedstock, divided in three main types of biomass categories will be used in this report:

(1) forest products and forests residues,

(2) energy crops and agricultural residues

(3) animal manure (organic waste)

Energy, which uses renewable energy resources, is extremely attractive for each country's economy to invest. The use of forest biomass is one of the most important sources of energy in the world. For example, about 55% of the 3.2 billion m3 of timber harvested annually in the world is firewood, which provides about 10% of the planet's energy demand. The following preconditions are necessary for the development of forest bioenergy:

- ✓ Available of required volumes of wood
- ✓ Available mechanisms of state regulatory and finances to support renewable energy sources
- ✓ Level of technology required to produce/consume the renewable energy
- ✓ Qualified personnel working in the field of bioenergy

3.1 FOREST BIOMASS POTENTIAL IN ARMENIA

The forest fund of Armenia is 459 thousand hectares in which timber stock is around 41.7 million m3 They are mountainous and are endowed with soil-protecting, wind-protecting and climate-regulating properties. Their significance and value are therefore invaluable. About 75% of forests in Armenia are managed by Hayantar SNCO (including 13 forest sanctuaries), and 25% are specially protected areas (state reserves, national parks, sanctuaries), which are managed by the relevant SNCOs. all under the Ministry of Environment. A small proportion of the established forest areas belong to the communities or they are located on Armenian lands, which are leased by other organizations (for example, the Armenia Tree Planting Project). Armenia does not actually have production forests for timber (or firewood). The dynamics of natural gas prices, the economic situation in rural communities, the unemployment rate, as well as the weak enforcement of forest protection regulations have led to ongoing deforestation and adverse changes in forest ecosystems. In order to prevent illegal logging, the National Assembly of Armenia in 2019 On July 9, 2012, it adopted the amendments to the Criminal Code, the RA Code on Administrative Offenses and the Law on Tariffs for Compensation of Damage Caused to Fauna and Flora as a Result of Environmental Offenses, proposed by the Ministry of Environment. Their purpose is to increase administrative and criminal liability for illegal logging and deforestation.

The areas covered by forests are unevenly distributed within the country, with about 68% located in the northeastern regions, 30% in southern Armenia, and only 2% in central part of the country. The reported volume of official cuttings done with sanitary purposes is more than 33 thousand cubic meters[2] , which is considerably less the consumption of logwood.

Though it is beyond the scope of this assessment to demonstrate the feasibility of using the forest biomass, the figures will be used to understand what are the volumes of fuel that needs to be replaced to meet the population demand for heat during winter times.

A Comprehensive Household Survey concluded that firewood is currently the most preferred type of fuel in rural as well as urban areas of the country. This preference is driven by existing socio-economic issues, specifically by two major elements:

1 Geyer, W.; Iriarte, L. Biomass for energy in Europe and the United States. In National Convention of the Society of American Foresters 2007

2 2017 Annual Report of the State Forest Monitoring Center, Yerevan, 2017

1. The low price for logwood;
2. Current technology used for heating (logwood stoves);

The regions located closer to the forest areas have a better access to cheap or even free of charge wood resources, which makes switching to other sources of energy economically not feasible. The connection between the preference for wood as fuel and forest proximity can be easily seen in the chart below. Based on this, we can preliminarily conclude that poverty is not the primary trigger for using wood as a fuel.

In the diagram below it can be easily spotted how symmetric is the connection between the access to forests and their logwood consumption. Tavush and Lori are the regions with the highest level of forest in the country, which can be easily seen in the figure below. Fuel consumption follows the same pattern on the graph, which demonstrates the link between the access to forest and consumption of logwood.

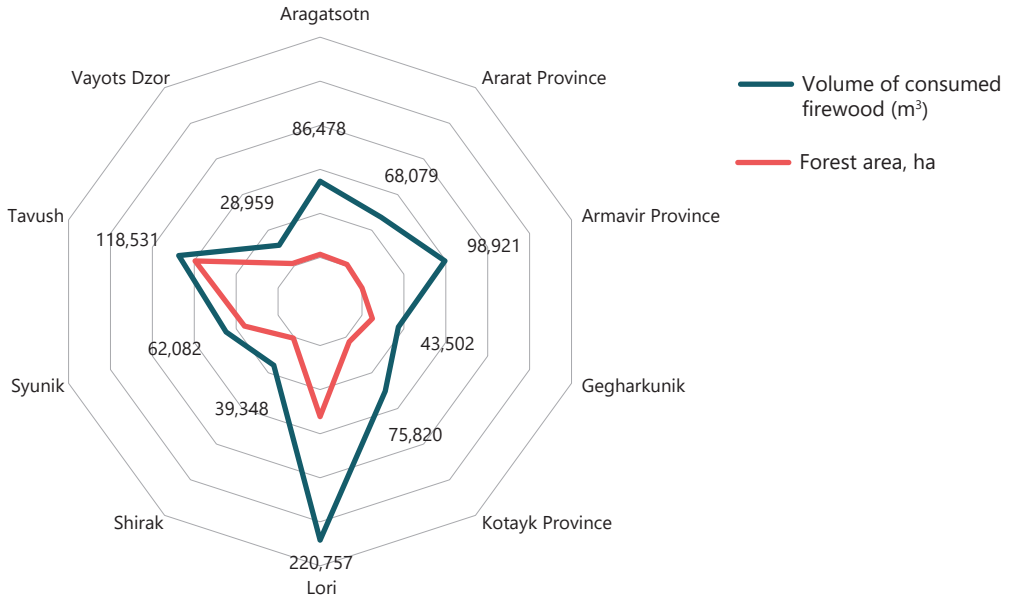


Figure 5 *Volume of consumed firewood during 2017-2018, m3 compared to forested areas in regions of Armenia*

The pattern is also the direct consequence of the Decision No. 1535-N of the Government of the Republic of Armenia "On establishing a privileged free procurement of firewood for families living in forest residences of the Republic of Armenia". It is directly incentivizing families living in proxime to forest areas to collect soft firewood free of charge. Adopted in 2011 the above-mentioned decision was possibly pursuing different goals, but today it should be updated re-considering the interests of all stakeholders.

Based on the discrepancy between official and unofficial data regarding the legal versus illegal cuttings, the forest seems to be also a good source of revenue. Therefore, people allowed to collect up to 8 cubic meters of soft wood may not qualify as the poorest population of the country. This requires immediate and direct state intervention.

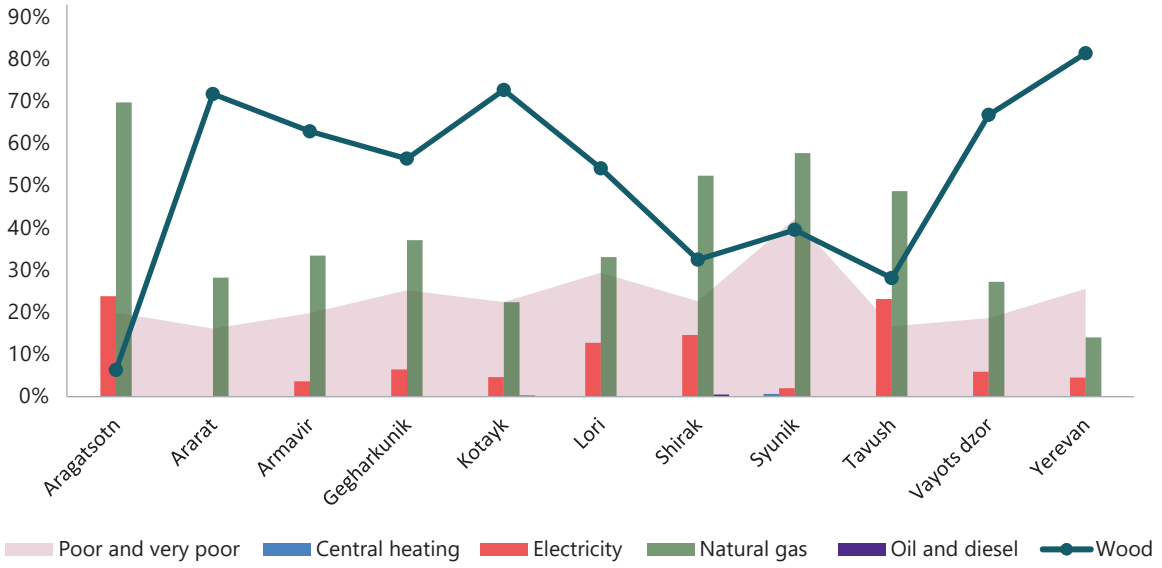


Figure 6. *Poverty level, forest cover and fuel choice for heating in the regions of Armenia according to Households*

Tavush, Lori and Syunik are the regions of the country which account for 82%[1] of the total forests of the country. All of them together summed up around 294 thousand hectares of forest in 2000. But in only 20 years, Armenia has lost 1,748 ha in the above-mentioned regions and a little more than 2,000 ha in the whole country which is around 0.6% of the total area.

Apart from the problem with deforestation, the data shows a deeply engraved pattern of solid fuel consumption in the country. A deeper analysis in the regions would reveal, for instance, one third of Tavush households using wood for heating, which makes 13% more than registered poor population. Similarly, in Lori, more than 50% of households are using wood for fuel but only 30% of them are officially qualified as poor. The accuracy of data on poverty might be an issue of debate, but still, the important conclusion of this is the big share of households using logwood for heating for reasons that are not necessarily connected to their income level.

Long-term negative changes in the ecological situation are observed in the areas subject to intensive logging. A good example of this is again the current state of forest ecosystems in Lori and Tavush.

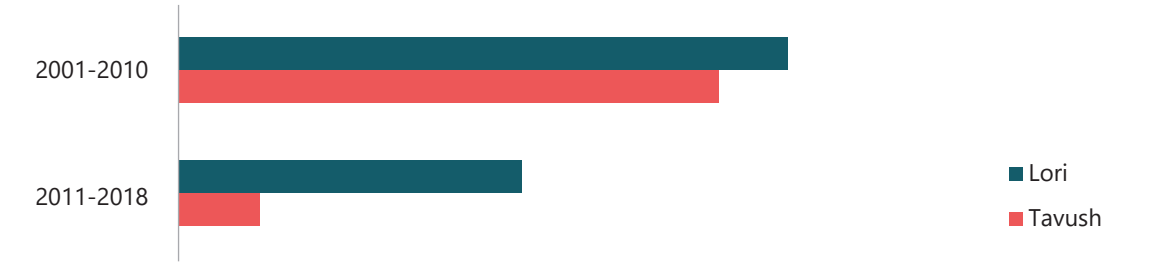


Figure 7 *Loss of forested area, ha*

The descending trend of deforestation areas in Lori and Tavush regions is representative for the whole country and is most probably an indication of the lately restrictions imposed by the authorities to forest areas. However, it might also mean bigger trees are targeted for logging.

1 Cadastre office or RA

The question mark can be raised because of the figure below, which indicates an ascending trendline in wood consumption. This should be treated as a wakeup call by the authorities because of the imminent threat of losing extended areas of forest in the nearest future.

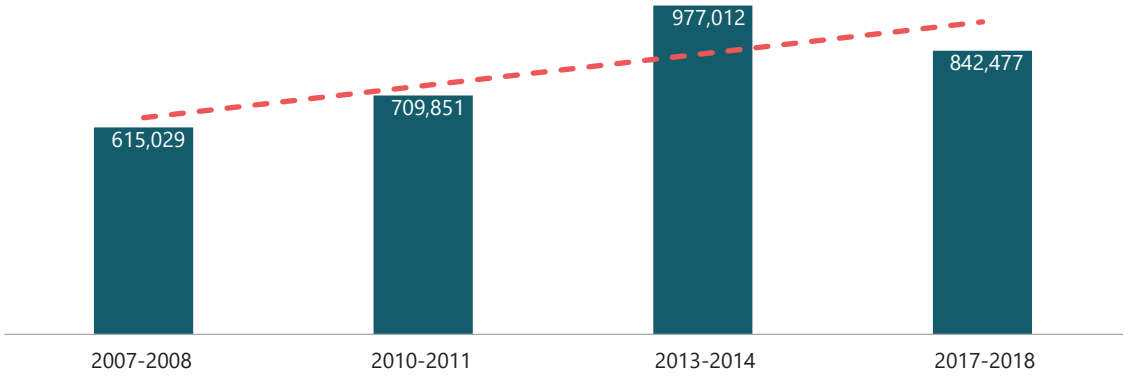


Figure 8 *Volumes of firewood used in the regions of the Republic of Armenia as a result of the firewood consumption market study (2007-2018), m3*

In conclusion, it should be noted that:

- Both official and unofficial sources of information reflect an increasing wood for energy consumption in the country;
- Poverty is not necessarily the driver for the increasing wood consumption trend, but forest proximity is;
- Regulatory framework should be improved to incentives demand for alternative sources of energy;
- There is a long-lasting tradition to use wood as fuel in almost all regions of the country and it will take time and effort to change it;

3.2 AGRICULTURE BIOMASS POTENTIAL

The main filed crops cultivated in Armenia are autumn-spring wheat, barley-rye, as well as oats, beets, buckwheat and corn. Other cereals ((Millet, sorghum, etc.)) are also grown in small quantities in Armenia but can be neglected for the purpose of this study. The harvesting process is common and only the storage depends much on the further use of the straw. Usually a part is used for fodder or animal bedding, some is crushed and mixed with the soil. The biggest part though, is burnt in the field, especially during grassy years. The average moisture of the straw after the harvesting is usually 14-17%, which makes it suitable for briquetting and/or pelletizing.

Two types of agricultural biomass potentials will be analyzed for the purpose of this analysis:

Theoretical potential - the maximum amount of terrestrial biomass which can be considered theoretically available for bioenergy production within fundamental bio-physical limits. In the case of biomass from agricultural crops, this represents the maximum productivity under theoretically optimal management of agriculture, considering limitations that result from temperature, solar radiation and rainfall. Official statistical data will be used for this purpose.

Market / Economic / Implementation potential refers to the share of the potential which meets economic criteria within given conditions (e.g. competition with fossil fuels or assumed carbon prices). This depends on both the cost of production and the price of the biomass feedstock.

In order to estimate the biomass potential of agricultural crops, it is necessary to estimate the amount of biomass residues obtained after collecting agricultural crops, which were conventionally included in Group 1 (wheat, barley, rye, oats, corn, sunflower) or crops conventionally included in Group 2 (vine, fruit trees) that are usually trimmed in the spring. To estimate the amount of agricultural residues and subsequent energy potential for agricultural crops the following table will be used:

Table 2 *The coefficient of output of biological waste generated in relation to the amount of harvest*

Crop	Biomass residue	The coefficient of output of biological waste generated in relation to the amount of harvest *t/t of grain, t/ha (vineyards, orchards, forests)*	Reference Heat Capacity, MJ/kg	Market availability factor, %
Winter Wheat	Straw	1.5	15	25
Winter Barley	Straw	1.3	15	25
Winter rye	Straw	1.5	15	25
Spring wheat	Straw	1.3	15	25
Spring barley	Straw	1.2	15	25
Spring rye	Straw	1.2	15	25
Oats	Straw	1.4	15	25
Spelt	Straw	1.5	15	25
Maize for grain	Stalk	1.3	16.8	65
Sunflower	Stalk	1.4	16.2	65
Fruit trees	Branches	1.2	17.9	95
Vine	Branches	0.8	15	97

Based the practical examples from countries in the region and following a pessimistic scenario for the estimations, the market potential of the agricultural residues will be calculated as the availability factor of the overall biomass available in the country.

According to official statistics six regions are leading in terms of biomass, as shown in the figure below. Shirak region is by far the champion, with an average 41,768 tons of cereals produced during 2017-2019.

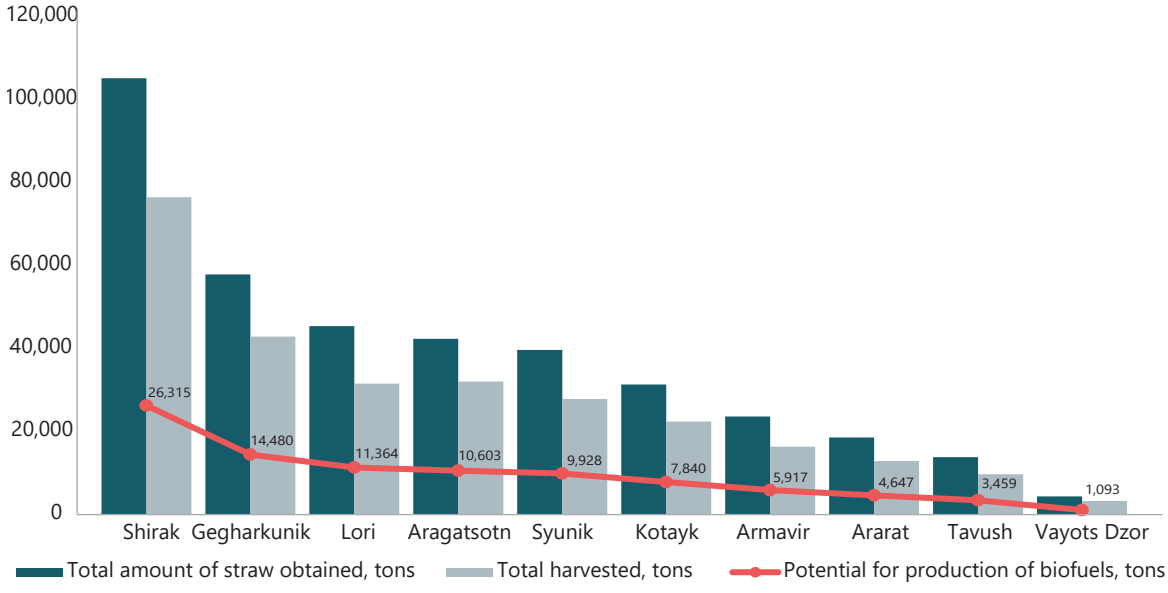


Figure 9 *Total residues generated from cereal crops in the Republic of Armenia by regions in 2017-2019, tons*

To better understand the specifics of each region and approximate potential technologies suitable to transform the major sources of raw material into fuel, a short screening of the local economies will be conducted. It will provide quality insights for the identification of necessary prerequisites for the market to get onto a faster path of development.

Aragatsotn (Արագածոտն) is a marz of Armenia. Located in the western part of the country, the number of its rural population is 3 times bigger than the urban. Thus, most of the population are engaged in agriculture, including farming and cattle-breeding. Being a major agricultural region, Aragatsotn contributes with 9.7% in the annual total agricultural product of Armenia. Around 79% (2,178 km^2) of the total area of the province are arable lands, out of which 25% (542 km^2) are ploughed. With an approximate area of 240 km^2 of farmlands are occupied by grains and dry seeds. Around 40% of the 47 km^2 of orchards in Aragatsotn are occupied by grapes. Potato farms occupy around 16 km^2, while vegetables are spread over 10 km^2 of farms.

The potential of biomass residues from orchards is comparatively low in the region. With an average 427 tons of residues per year it represents only 2.7% of country total.

Following official statistics, the main cereal crops grown in the region are winter wheat and spring barley, as shown in the figure below. The average quantities of straw suitable for biomass fuel production during 2017-2019 were totaling more than 20 thousand tons per year.

With an average lower calorific value of 15 Mj/kg the total energy potential of the biomass from cereal crops can be estimated at 300 TJ. The use of biomass fuel would replace 13,300 cubic meters of logwood.

As in the highlands of Mount Aragats, particularly in the regions of Aparan and Talin, cattle-breeding is more common in the rural communities, there are considerable quantities of manure to be considered in estimating its potential to produce biofuels. With an average of 365 thousand tons of manure per year, there is good potential to obtain additional 1,297,546 TJ of energy from 1/2 manure quantity collected every year.

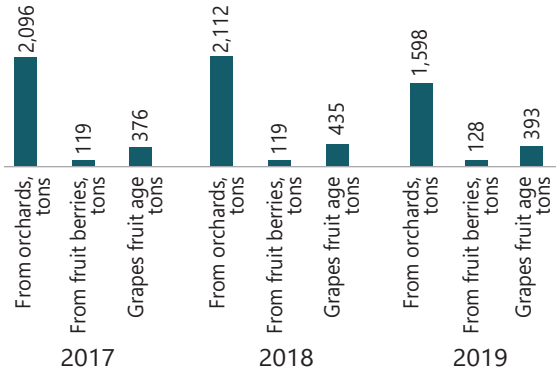


Figure 10. *Vegetal residues, Aragatsotn province, tons*

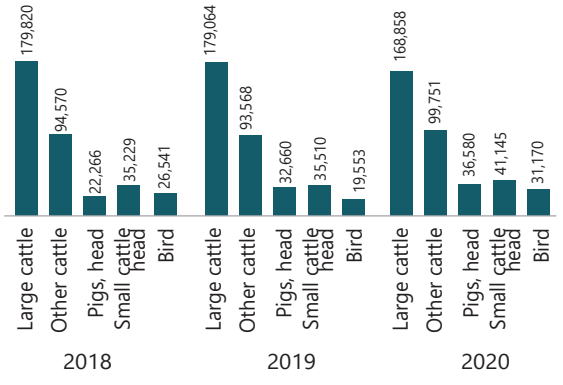


Figure 11. *Animal manure, Aragatsotn, tons*

Ararat (Արարատ), is a marz of Armenia. The province is named after the biblical Mount Ararat. It is bordered by Turkey from the west and Azerbaijan's Nakhchivan Autonomous Republic from the south. It surrounds the Karki exclave of Nakhichevan which has been controlled by Armenia since its capture in May 1992 during the Nagorno-Karabakh War. Domestically, Ararat is bordered by Armavir Province from the northwest, Kotayk Province from the north, Gegharkunik Province from the east, Vayots Dzor Province from the southeast and the city of Yerevan from the north. Two former capitals of Armenia are located in the modern-day Ararat Province, Artaxata and Dvin. It is also home to the Khor Virap monastery, significant as the place of Gregory the Illuminator's 13-year imprisonment and the closest point to Mount Ararat within Armenian borders.

Being located at the fertile Ararat plain, the province contributes with 15% in the annual total agricultural product of Armenia. Around 75% (1,567 km2) of the total area of the province are arable lands, out of which 17.23% (270 km2) are ploughed.

Orchards mainly produce grapes, apricot and peach. Other products include pear, apple, melon, watermelon, eggplant, grains and dry seed. Ararat is among the leading provinces of Armenia in wine production in terms of grape cultivation and wine export (along with the provinces of Ararat and Vayots Dzor).

The irrigation infrastructure of the province is quite developed. 90% of the farmlands are irrigated, mainly using canals opened from the rivers of Vedi and Azat. The Geghanist village has a specialized plant in producing fertilizers and irrigation system design.

The province has 2 large poultry farms in the village of Kaghtsrashen and the town of Masis. Recently, fish farming has significantly developed in the province. The largest fish farming ponds are located at the vicinity

of Armash village.and Vayots Dzor).The irrigation infrastructure of the province is quite developed. 90% of the farmlands are irrigated, mainly using canals opened from the rivers of Vedi and Azat.

Considerable resources of straw from cereal is obtained in the region. With an average of 23,668 tons of straw per year, the energy embedded in this raw material accounts for 279 TJ. This amount of energy would replace approximately 20,000 tons of logwood currently consumed by households in the region.

Using the assumption that only 25% of the residues can be used for fuel production an approximate 4,647 tons of fuel can be produced. There is a considerable potential of bioenergy to be produced from animal breeding residues in Ararat. With an average 228,670 tons of cattle manure per year, there is great potential for the region to implement biogas projects for power and heat generation. With a share of at least 50% use for biogas production, the quantity of energy to be produced is about 830,371 TJ.

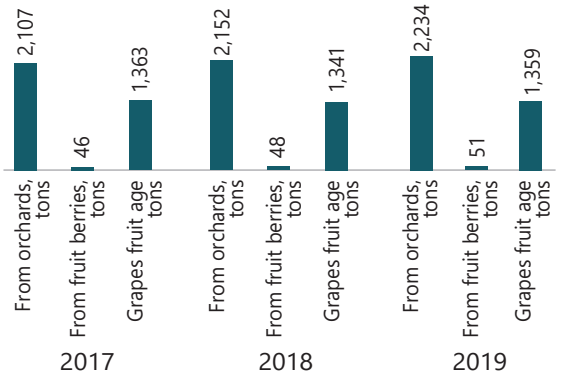


Figure 12. *Vegetal residues, Ararat province, tons*

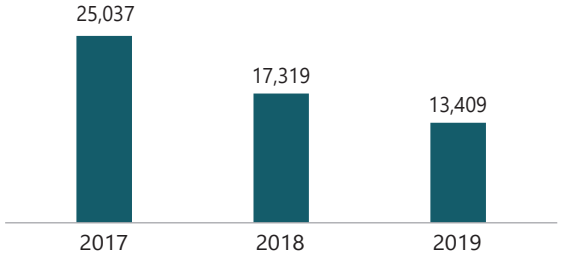


Figure 13 *Cereal residues, Ararat province, tons*

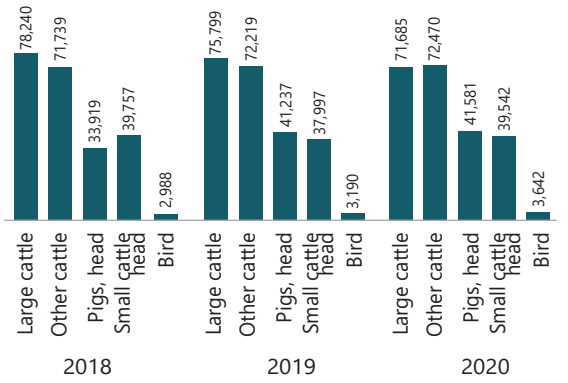


Figure 14 *Animal manure, Ararat, tons*

Armavir (Արմավիր), is a *marz* in the western part of Armenia. Located in the Ararat plain dominated by Mount Ararat from the south and Mount Aragats from the north, the province›s capital is the town of Armavir while the largest city is Vagharshapat (Etchmiadzin). The province shares a ٧٢ km - long border with Turkey to the south and west. Occupying a major part of the fertile Ararat plain, Armavir Province has a major contribution in the agricultural sector of the Republic of Armenia. The economy of the province is largely based on agriculture, including farming and cattle-breeding. Around 78% (970 km^2) of the total area of the province are arable lands, out of which 40% (388 km^2) are ploughed. The main crops are grapes, apricot, peach, plum, grains, dry seeds and vegetables. Currently, the province has a contribution of 17.8% in the annual total agricultural product of Armenia. Armavir is among the leading provinces of Armenia in wine production in terms of grape cultivation and wine export (along with Ararat and Vayots Dzor).

Similar to the previously presented regions, Armavir is also characterized by considerable volumes of cereal crop residues. With an average of 23,668 tones, the quantity of energy embedded in the straw is about 355 TJ. The quantities of biomass useful for the production of fuel may go up to 6,000 tones.

The quantities of manure generated because of animal breeding is high, the region being 4th the largest producer of this resource. With an average of 354 thousand tons of manure

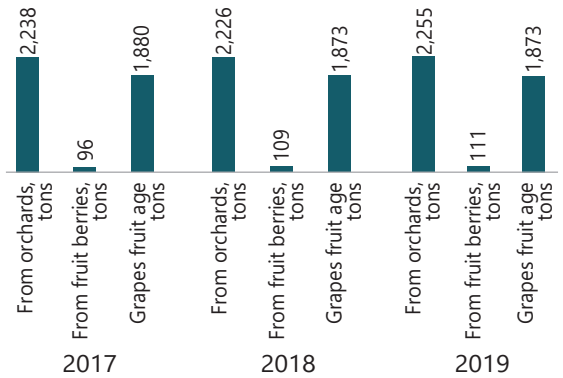


Figure 16 *Vegetal residues, Armavir province, tons*

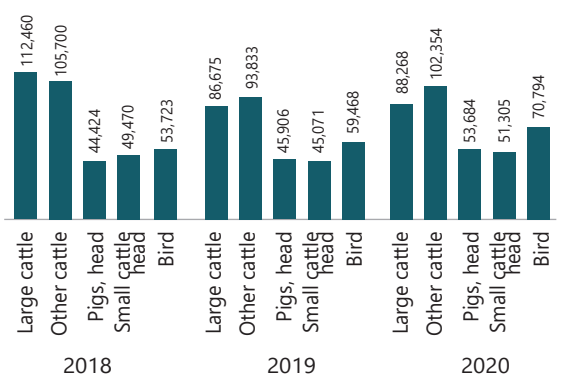


Figure 15 *Animal manure, Armavir, tons*

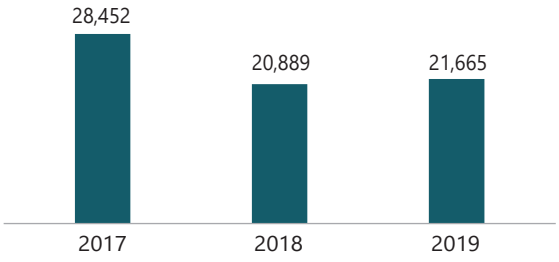


Figure 17 *Cereal residues, Armavir province, tons*

produced per year and 50% share of use for energy purposes, there is a good chance that 1,521,389 TJ of energy can be produced and supplied to the grid.

Gegharkunik (Գեղարքունիք), is marz of Armenia. Its capital and largest city is the town of Gavar. Gegharkunik Province is located at the eastern part of Armenia, bordering Azerbaijan and the Shahumyan Region. With an area of 5,348 km2, Gegharkunik is the largest province in Armenia. However, approximately 24% or 1,278 km2 of its territory is covered by Lake Sevan, the largest lake in Transcaucasia and a major tourist attraction of the region. The economy of Gegharkunik Province has a predominantly agricultural orientation, including farming and cattle-breeding. It has a share of 18% in the annual total agricultural product of Armenia. Around 65% (3,487 km2) of the total area of the province are arable lands, out of which 27.3% (951.5 km2) are ploughed. Around 60,000 farms in Gegharkunik are operated by the private sector. The main crops are potato and grains.

The residues obtained from cereals have the biggest potential, as indicated in figure 18. The average quantities collected yearly are around 58,000 tons placing the region on second place for the potential of this resource after Shirak. If one quarter of this potential is to be considered as useful for solid fuel production 14.5 thousand tones will be made available every year for briquettes and/or pellets.

Once produced and consumed, the biomass fuel would replace 15,500 cubic meters of logwood, which is 36% of the current consumption of the region.

The biggest potential of residues that could be used for production of biofuels is with manure from animal breeding. Statistical data indicates that the region is the biggest generator of animal manure in the country which obviously should be regarded as a key element for the biofuel development strategy within the region. With almost half a million tons of manure produced yearly, the region could produce 1,639,926 TJ of energy.

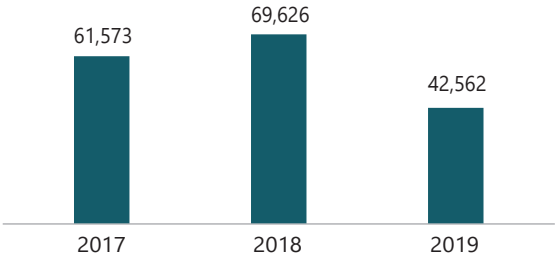


Figure 18 *Cereal residues, Gegharkunik province, tons*

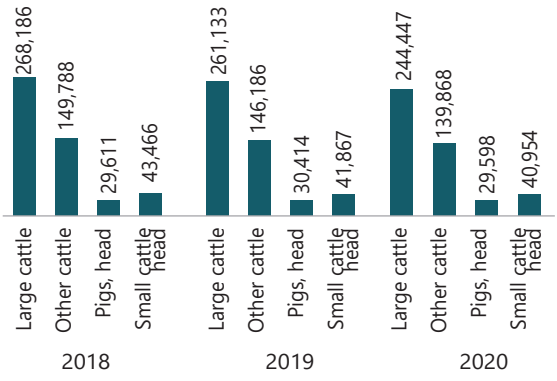


Figure 19 *Animal manure, Gegharkunik province, tons*

Kotayk (Կոտայք), a marz of Armenia. It is located at the central part of the country. Its capital is Hrazdan and the largest city is Abovyan. It is named after the Kotayk canton of the historic Ayrarat province of Ancient Armenia. Kotayk is a major center for agricultural products and cattle-breeding in Armenia, forming 6% of the annual total agricultural product of Armenia. Around 74% (1,546.4 km^2) of the total area of the province are arable lands, out of which 24.4% (378 km^2) are ploughed. A total of 36,125 farms in Kotayk are operated by the private sector or through cooperatives. The agricultural products of the province are divided as follows: 40% provided by cattle-breeding, 14% by tobacco processing, 10% by fruits, 8% by vegetables, 28% by other products including grains and dry grains. The orchards mainly produce grapes, apricot, peach and apple.

There is good potential of straw in the region. With an average of 31 thousand tons of straw produced every year, approximately 8 thousand could be transformed in solid fuel. With an average low calorific value of 17.5 MJ/kg, the energy produced by burning this fuel would generate 137 Tera Joules of energy. By using the biomass fuel, the region can substitute the consumption of approximately 10 thousand cubic meters of logwood.

The fuel produced from orchards and vineyards residues in the region would substitute additional 1.7 thousand cubic meters of wood, which would total 31,620 MJ together with the fuel produced from straw.

Residues obtained from animal breeding represents an important share of bioresources potential of the region. With an average of 315 thousand tons of manure, the potential of using at least 50% of this for energy production would result in 1,228,647 TJ.

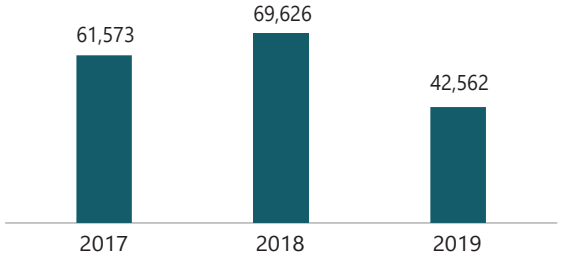


Figure 20 *Cereal residues, Kotayk province, tons*

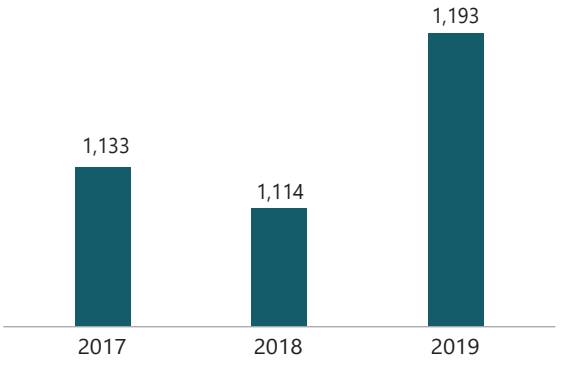


Figure 21 *Vegetal residues, Kotayk province, tons*

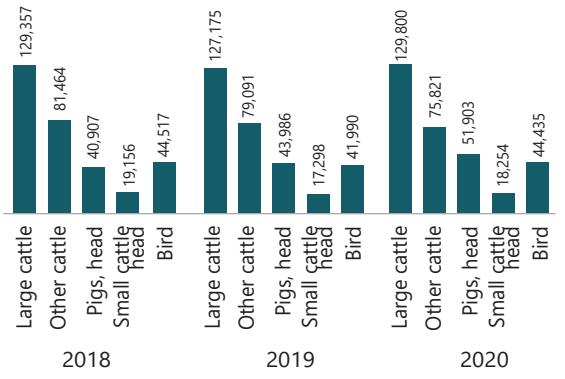


Figure 22 *Animal manure, Kotayk province, tons*

Lori (Լոռի) is a marz of Armenia. It is located in the north of the country, bordering Georgia. Vanadzor is the capital and largest city of the province. As of 2016, the province has a contribution of around 6% in the annual total industrial product of Armenia. Lori is a major center for metallurgical business, building materials production, as well as dairy products. It is home to the UNESCO World Heritage Sites of Haghpat and Sanahin monasteries and the well-preserved Akhtala monastery, where Armenians, Georgians, and Greeks make an annual pilgrimage on September 20–21.

The province is served by the Stepanavan Airport. The agriculture of Lori forms around 7.5% of the annual total agricultural product of Armenia. Approximately, 40% of the population in Lori are involved in agricultural activities, including farming and cattle-breeding. Almost 66.3% (2,511.5 km2) of the total area of the province are arable lands, out of which 17% (421 km2) are ploughed. The main crops of the province are grains, followed by potato and vegetables.

The region is placed third as potential of straw from cereals. With an average ranging between 45-46 thousand tons per year, the quantities to be potentially converted into fuel are around 11 thousand tons, translating it into 170 TJ of energy.

There are also considerable amounts of vegetal residues from orchards and vineyards. Though, insignificant comparing to other types of biomass, they should be considered because of the growing trend.

The biggest potential for bioenergy is, according to the official statistics, held be animal manure. The region is among the first 5 top rated provinces of the country, in this sense. With an average of 331 thousand tons of animal manure, the potential to transform 50% of this quantity in biogas would generate at least 1,109,988 TJ.

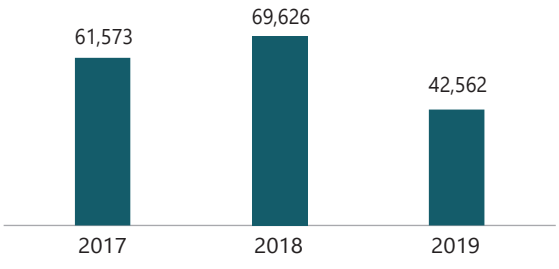


Figure 23 *Cereal residues, Lori province, tons*

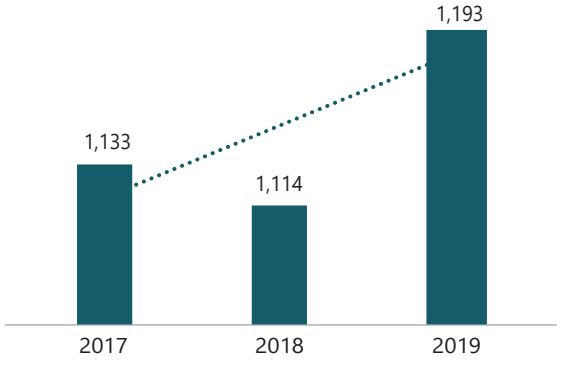


Figure 24 *Vegetal residues, Lori province, tons*

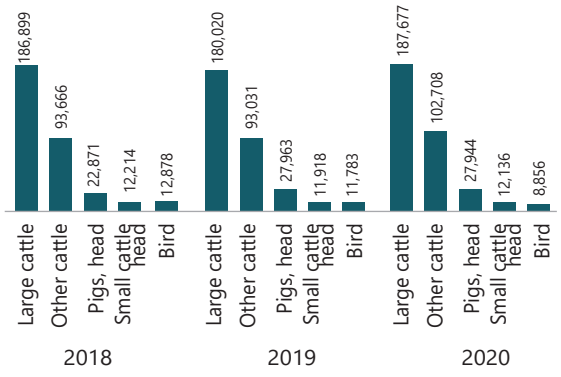


Figure 25 *Animal manure, Lori province, tons*

Shirak (Շիրակ) is a marz of Armenia. It is located in the north-west of the country, bordering Turkey in the west and Georgia in the north. Its capital and largest city is Gyumri. The economy of the province is mainly based on agriculture, including farming and cattle-breeding. It has a share of 11.6% in the annual total agricultural product of Armenia. Around 80% (2,145.5 km^2) of the total area of the province are arable lands, out of which 36.7% (787 km^2) are ploughed.

The fertile Shirak plain is the largest producer of grains and potato in Armenia. The irrigation system in the province is highly developed.

The official statistics ranks the province first for its straw resources. With an average of 105 thousand tons produced per year, it would be economically reasonable to collect and produce up to 30 thousand tons of biomass fuel. This quantity would embed 460 TJ of energy which would substitute around 33 thousand cubic meters of wood.

There is also a considerable potential for residues obtained from animal breeding. The region ranks second for its potential of manure. The average quantities of manure collected every ear would allow production of 1,403,886 TJ energy, if only 50% of the residues are used. The large potential of biomass residues in this region is a subject of careful analysis further. Because the logwood consumption in the region is one of the lowest in the country, the exploration of the biomass and other biofuel potential specifically in this region is paramount.

Also, the current level of energy poverty in the region could also find a solution in developing alternative sources of energy

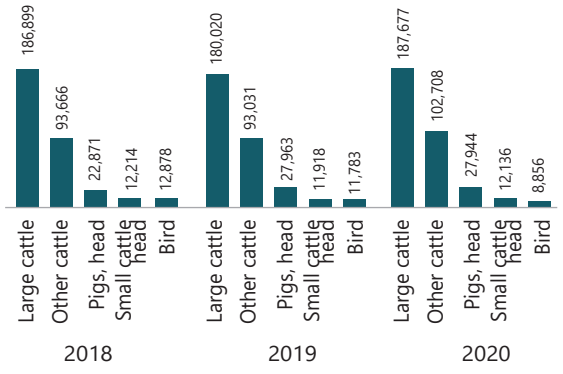


Figure 26 *Animal manure, Shirak province, tons*

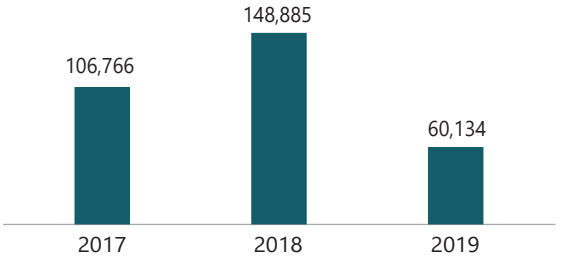


Figure 27 *Cereal residues, Shirak province, ton*

Syunik (Սյունիք) is the southernmost province of Armenia. It is bordered by the Vayots Dzor Province from the north, Azerbaijan's Nakhchivan Autonomous Republic exclave from the west, the de facto independent Nagorno-Karabakh Republic from the east, and Iran from the south. Its capital and largest city is the town of Kapan.

Around 74% (3,336 km^2) of the total area of the province are arable lands, out of which 13.2% (440 km^2) are ploughed.

The rural population is mainly involved in agriculture and cattle-breeding. The province contributes 6.5% of the annual agricultural product of Armenia. The main crops are grains, dry grains, potatoes and vegetables.

If properly collected, winter wheat alone could provide around 15 thousand tons of residues suitable for biofuel production. Overall, the cereal crops would provide more than 21 thousand tons of biomass. The highest potential though is held be the animal manure, which maintains a steady dynamic during 2017-2109.

The amount of energy that could be generated from these residues are about 315,000 MJ from cereals as well as 973,926 TJ from the animal manure.

Due to small quantities of biomass collected from orchards they can be neglected for the purpose of this analysis.

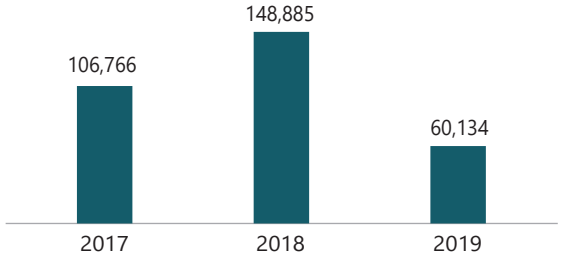


Figure 28 *Cereal residues, Syunik province, tons*

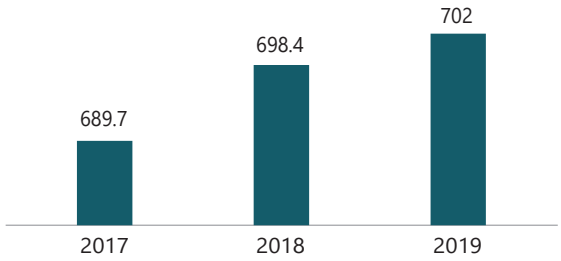


Figure 29 *Vegetal residues, Syunik province, tons*

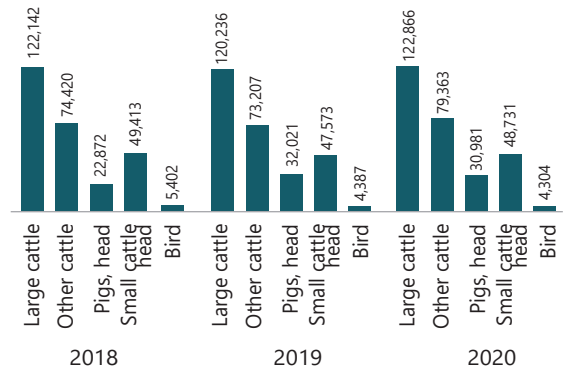


Figure 30 *Animal manure, Syunik province, tons*

Tavush (Տավուշ), is a province of Armenia. It is located at the northeast of Armenia and bordered by Georgia from the north and Azerbaijan from the east. It is domestically bordered by the Gegharkunik Province from the south, Kotayk Province from the southwest and Lori Province from west. The capital and largest city of the province is the town of Ijevan.

Tavush has a poor agricultural index with only 4.8% of share in the total annual agricultural product of Armenia. Around 41% (1,108 km^2) of the total area of the province are arable lands, out of which 23% (256 km^2) are ploughed. The population in many rural communities are mainly involved in farming, cattle-breeding and pig farming. The main crops are grains and grapes.

Thus, the overall potential in the region is lower comparing to other regions of the country, the province has good chances of harness the good potential of cereal straw and animal manure

With an average of 14 thousand tons of straw produced per year, there is a good chance that one quarter of the residues can be processed into fuel in an economically reasonable way. Additionally, developing the biomass sector will have a positive impact on the growing logwood consumption in the region.

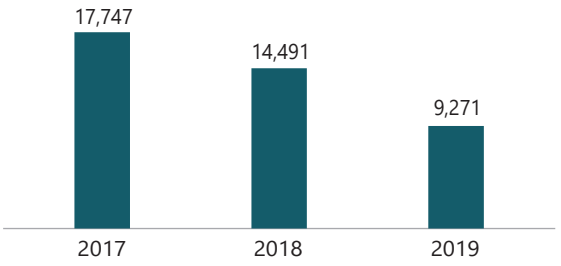


Figure 31 *Cereal residues, Tavush province, tons*

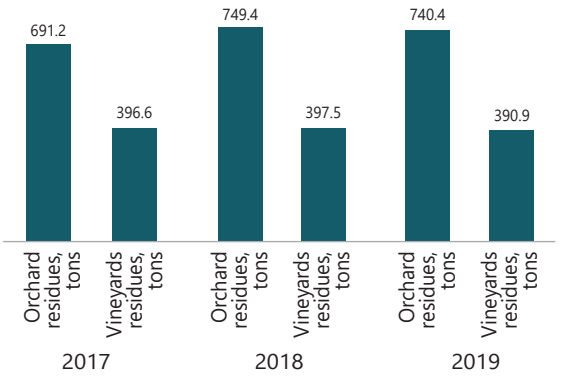


Figure 32 *Vegetal residues, Tavush province, tons*

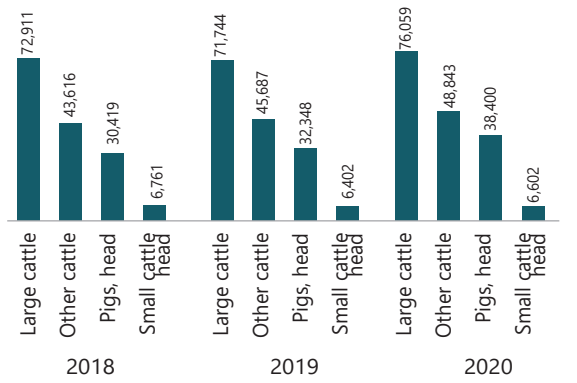


Figure 33 *Animal manure, Tavush province, ton*

Vayots Dzor (Վայոց Ձոր), is a province of Armenia. It lies at the southeastern end of the country, bordering the Nakhichevan exclave of Azerbaijan to the west and the Shahumyan Province of the Artsakh Republic (de jure Kalbajar District of Azerbaijan) to the east. It covers an area of 2,308 km2. With a population of only 53,230 (2002 census), it is the most sparsely populated province in the country. The capital and largest city of the province is the town of Yeghegnadzor.

Vayots Dzor has the poorest agricultural index among the Armenian provinces, forming 2.2% of the annual total agricultural product of Armenia. Around 82.5% (1,903 km^2) of the total area of the total area of the province arable lands, out of which only 8.5% (162 km^2) are ploughed.

However, agriculture -including farming and cattle-breeding- is the most common activity in the province. Agricultural crops include apricot, cherry, pear, peach, apple, quince, plum, melon, walnut, grapes and berries. Cattle-breeding includes wool-bearing, goat farming, poultry farming and beekeeping. Vayots Dzor is among the leading provinces of Armenia in wine production in terms of grape cultivation and wine export (along with the provinces of Ararat and Armavir).

With more than 4 thousand tons of straw available every year, only one thousand could be economically reasonable processed into fuel. This is not big potential comparing to other regions, nevertheless it will bring additional value at local level and will stimulate the use of alternative sources of energy. There is a similar situation with orchard residues which are few to consider for processing, considering the technical barriers while collecting, processing for transportation and delivery to the place of production.

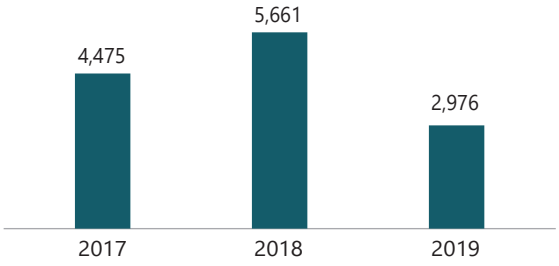


Figure 34 *Cereal residues, Vayots Dzor province, tons*

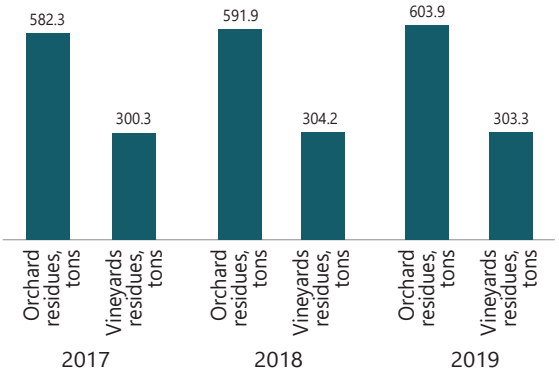


Figure 35 *Vegetal residues, Vayots Dzor province, tons*

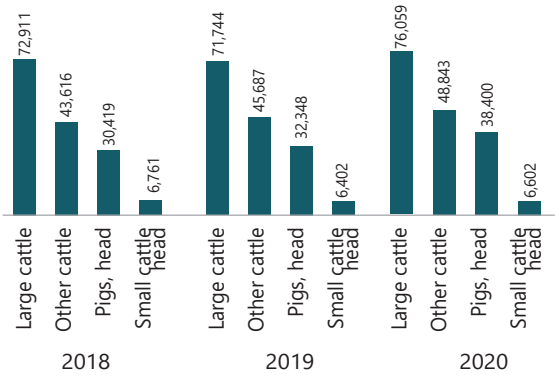


Figure 36 *Anima manure, Vayots Dzor province, tons*

3.3 ENERGY CROPS - SHORT ROTATION COPPICE (SRC)

The scarcity of forest resources led to an increasing interest for fast-growing plantations, of so-called energy crops. As mentioned above, Armenia is a sparsely forested country, where the forests are purely mountainous, with a small stock of natural wood (41.7 million cubic meters) and 0.1 hectare of forest area per capita (Khurshidyan 2000). There are no industrial cuttings in the forests of Armenia and the timber and phytosanitary procured from other cuttings (sanitary, care, etc.) are officially insignificant. The experience of developed countries proves the interest towards energy crops because they offer an attractive alternative of growing faster than conventional forests. Another benefit of cultivating energy crop is their ability to grow on marginal and non-agricultural lands. Almost all communities of Armenia are registering such land and the possibility of using this land for energy purposes offers tremendous opportunities. Planting energy corps could be part of community forestry development programs. Furthermore, it is especially important now, as Armenia has undertaken to double the forest mass by 2050.

At the same time, planting energy crops in Armenia is not new having the first attempts done in 1994 in Armavir province. Fast growing clones of American poplar imported from the USA have been planted for testing purposes. Nonetheless excellent results have been achieved, no major expansion in planting energy crops in the country has been assessed so far.

The alternatives available and suitable for Armenia are obvious. Depending on a number of factors, these can resemble to wooden or herbaceous energy crops. For each group, the most representative crop will be presented and analyzed.

3.3.1 Woody biomass – Salix, energy willow [1]

Energy willow is a ligneous and shrubby plant, having a rapid growth up to 3 – 3.5 cm/day and a lifespan of 20-25 years. Industrial plantations of different hybrids of Salix achieving these indicators have been planted in Balkan countries[2]. The closest country having industrial plantations and experience in growing energy willow is Ukraine. Different varieties and hybrids in 2-3 years can grow at shoots height of 6-7 m with a shoot's base diameter of 6-8 cm, in those countries. Beginning with the 2-3rd year a yield of at least 35 t/ha/year (wet) biomass can be obtained in form of raw biomass – bales, chips, or straight rods and pellets or briquettes.

- **Characteristics**

1. Rapid growth: up to 3-3,5 cm/day;
2. High caloric value: 4900 kcal/kg ~ 19-21 MJ/kg ~ 5.5 KW/kg of dry biomass;
3. Remarkable adaptability to different pedoclimatic conditions;
4. Constant biomass harvest for 20-25 years. Applying adequate technology, annual biomass yield of over 60 t/ha can be obtained;
5. Suitable for soils with water excess, polluted and degraded soils

- **Utilization areas**

1. Biomass production for heat, electric energy and pellet/briquette production
2. Protective curtains erection for field crops, as well as for roads and railways
3. Soil stabilization: sloping grounds and riverbanks erosion prevention, industrial ash depositories stabilization, agricultural land wind erosion
4. Improvement of degraded soils and their reintroduction into the production cycle
5. Natural wastewater treatment and soil phytoremediation
6. Drainage of soils with water excess

Salix develops very well under temperate climate conditions, with average annual temperatures of 8-12 ° C. It does not demand that much light, as long as the recommended densities are satisfied. Tolerates frost up to – 30 ° C and moderate drought. It can be grown on different soil types, supporting a pH between 3.5 and 10, the ideal value being between 5.5 to 7.5. Has a zero tolerance to salty soils. Yields depend on soil quality, climate and water availability. Out of

1 http://www.grpanderson.com/en/

2 The opportunity of growing Salix in Armenia should be tested and scaled up based on the achieved results

these elements water availability is the by far the most required for the yield maximization. In given sense if there are no natural conditions perfectly suitable, irrigation needs to be implemented to reach maximal yields and profit.

- **Land preparation**

Soil preparation begins in the year before the establishment of the plantation by removing the weeds by administration of non-selective (total) herbicides. After removing the vegetation, the land is deeply mellowed after which is being plowed and disc/roto harrowed. Once the soil is prepared basic fertilization may be conducted. At early spring land should be ready for hosting Salix cuttings.

- **Planting material**

For the establishment of the plantation there are selected energetic willow varieties and hybrids, each adapted to specific soil and climate conditions. Planting material – cuttings (Pic. 1), must be of good quality and certified.

More detailed information regarding the species of willow can be found in the checklist for Cultivars of Salix L. that includes all possible cultivar names with comments, by FAO.[1]

Picture 1 *Salix cuttings*

- **Planting**

Usually accepted time for planting is during the spring as early as possible, when there is moisture in the soil. Planting is done in twin rows with distances in between, to allow the access for maintenance, harvesting and transport mechanization. Axial plants distance in the row is 75 cm, distance between two rows is 75 cm while the space between twin neighboring rows is 1,5 m. This way a planting density of ~14.000 cuttings/ha is obtained. Planting can be done mechanically or manually. Manual planting requires 8-9 man/day/ha. Mechanical Seeding Rate: 3.000 Cuttings/hr (2 rows planter at 3.6 km/h).

Picture 2 *Salix mechanical planting with three-raw planter*

- **Yields and harvesting**

Yield is eventually all that matters in this business' sense. High yields may be established in most of the East Europe, even on low quality soils, in case there is enough water through vegetative season. Climate changes have caused rapidly growing arid conditions thus making irrigation a must (at least REBINA consider it so). On the picture 3 a two-year-old irrigated and non-irrigated plant, willows' response to water shall be self-explanatory.

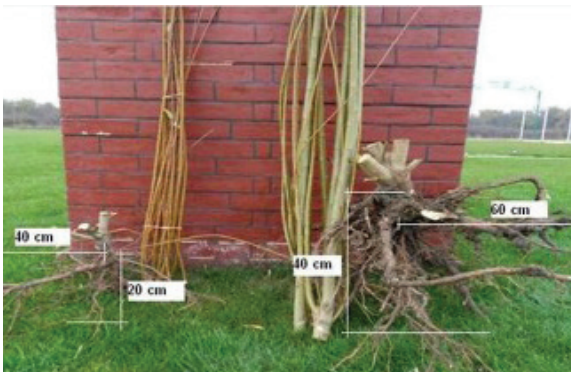
On properly maintained plantations with the irrigation system in place annual yields of 60-70 t/ha (wet mass at harvesting) may be reached. Optimal harvesting frequency is every second year, thus making harvesting mass of 130 or more t/ha. To gain more tangible image it would require a bundle of Salix to weight ~9 kg since there are 14.000 plants/ha. Without irrigation over last 5-6 years average yields reached at the most 30-35 t/ha/year on well administered plantations.

The first harvesting is usually performed in the 2 or 3rd year i.e. when the yield exceeds 25-30t/ha. Harvesting frequency is in direct relation to the yield and defers from region to region whereas in Armenia harvesting frequency should be

1 Checklist for Cultivars of Salix L: http://www.fao.org/forestry/44983-0370ab0c9786d954da03a15a8dd4721ed.pdf

performed bi-annually. Harvesting happens when the plants shed their leaves, in the vegetative rest period from November until March.

Specialized machines cut the rods in various shapes: in form of chips, which are collected in trailers and piled in sheds, wrapped in round bales of 400-500 kg stored in open space or as straight shoots – depending on the end user requirements. Moisture content at harvest is about 45-50+%. After a storage period of about 2-3 months bales left on the field due to draught and the sun spontaneously decrease moisture to 10% -20% requiring no sheds. Such stored biomass does not lose any quality in time.



Picture 3 *Root of two-year-old of irrigated and non-irrigated plant*

Picture 4 *Harvesting of Salix*

- **Plantation erection and biomass production cost**

A rough cost brake down €/ha would be:

CAPEX	Eur
Planting material (cuttings)	1.400
Soil preparation	1.000
Irrigation system	1.000
TOTAL	3.400
OPEX (annually) Harvest, maintenance, land lease	300

Based on the experience of other countries, the plantations do not have to be large in area. In countries like Sweden and Germany they occupy small areas in different communities. The same model is recommendable to Armenia, where marginal and depleted land could be used for erecting new energy crop plantations. It is desirable to plant energy SRC in deforested or sparsely forested regions such as Armavir, Aragatsotn, Shirak, Kotayk. An average of 15 to 60 ha of willow can be planted in each community, but a more detailed feasibility plan is required to provide more detailed recommendations.

3.3.2 Herbaceous biomass – Miscanthus

Miscanthus is a biomass crop that has a very regular annual cycle and demands little maintenance once the crop is mature. Establishing the crop as mature will take 2 to 3 years at which time the crop can be harvested in the very early spring allowing it to grow again and be re-harvested at a similar stem length the following year. The crop will start growing in spring and continue throughout the summer. Once growth slows and ceases in the fall, surplus nutrients, held in the stems, start to move back down towards the rhizome in the ground for winter storage. This assists in the reduction in moisture of the harvested crop allowing it to be baled soon after cutting. The whole process is repeated with the mature rhizomes growing fresh shoots that are harvesting again the following year. This will repeat annually for as many as twenty years.

Miscanthus is a hybrid sterile crop and as such does not reproduce through pollination. In order to create new fields of freshly grown plants, rhizomes must be propagated through division and then replanted.

- **Characteristics**

1 Rapid growth: up 2 m m/year by late August of the year of planting

2 High caloric value: 4,250 kcal/kg ~ 17.8 MJ/kg ~ 4.9 KW/kg of dry biomass

3 Remarkable adaptability to different pedoclimatic conditions

4 Constant biomass harvest for 20-25 years. Applying adequate technology, annual biomass yield of over 30 t/ha can be obtained

5 Suitable for soils with water excess, polluted and degraded soils

- **Utilization areas**

Miscanthus is mainly used as raw material for solid biofuels. It can be burned directly or processed further into pellets or briquettes. It can also be used as raw material for liquid biofuels or biogas. Alternatively, it is possible to use miscanthus as a building material, and as insulation. Materials produced from miscanthus include fiberboards, composite miscanthus/wood particleboards, and blocks. It can be used as raw material for pulp and fibers as well as molded products such as eco-friendly disposable plates, cups, cartons, etc. Miscanthus has a pulp yield of 70–80% compared to dry weight, due to the high holocellulose content. The pulp can be processed further into methylcellulose and used as a food additive and in many industrial applications. Miscanthus fiber provides raw material for reinforcement of bio-composite or synthetic materials. In agriculture, miscanthus straw is used in soil mulching to retain soil moisture, inhibit weed growth, and prevent erosion. Further, miscanthus' high carbon to nitrogen ratio makes it inhospitable to many microbes, creating a clean bedding for poultry, cattle, pigs, horses, and companion animals. Miscanthus used as horse bedding can be combined with making organic fertilizer. Miscanthus can be used as a healthy fiber source in pet food.

- **Management**

A limited amount of herbicide should only be applied at the beginning of the first two seasons; after the second year the dense canopy and the mulch formed by dead leaves effectively reduces weed growth. Other pesticides are not needed. Because of miscanthus' high nitrogen use efficiency, fertilizer is also usually not needed. Mulch film, on the other hand, helps both M. x giganteus and various seed based hybrids to grow faster and taller, with a larger number of stems per plant, effectively reducing the establishment phase from three years to two. The reason seems to be that this plastic film keeps the humidity in the topsoil and increases the temperature. Miscanthus as a crop is moderately or highly tolerant of multiple environmental stressors, specifically, heat, drought, flooding, salinity (below 100 mM), and cool soil temperatures (down to −3.4 °C). This robustness makes it possible to establish relatively high-yielding miscanthus fields on marginal lands.

- **Planting material**

Two methods of propagation are currently used in the UK - rhizome division and micropropagation. Rhizome division is favoured because it is less expensive and generally produces more vigorous plants. To produce new planting material, two or three-year-old plants are split whilst dormant, using a rotary cultivator, and the rhizome pieces collected for re-planting. A 30-40-fold increase in plants can be achieved this way over a period of 2-3 years, depending on soil conditions. Rhizome pieces must have at least 2-3 'buds' and must be kept moist before re-planting. This is best achieved by keeping rhizomes under cold-storage conditions, (<4 degrees Celsius) possibly for up to a year. The optimal planting density for either propagation system is 20,000 plants/ha, but this may vary slightly from site to site. Rhizomes need to be planted to allow for some expansion of the plant during the life of the crop and at a soil depth of 5-10 cm. The optimal planting date for rhizomes is March-April. Early planting takes advantage of spring-time soil moisture and allows an extended first season of growth. This is important because it enables larger rhizome systems to develop. These are more robust in future years and allows the crop to tolerate drought and frost better. For the establishment of the Miscanthus plantation there are a number of hybrids, each adapted to specific soil and climate conditions. Planting material – cuttings (Pic. 5), must be of good quality. Recommended varieties for Armenia may be: Giganteus. Additional information can be requested from official producers.

Picture 5 *Miscanthus rhizomes*

- **Planting**

Thorough site preparation is essential for good establishment, ease of subsequent crop management and high yields. As the crop has the potential to be in the ground for at least 20-25 years, it is important that it is established correctly to avoid future problems. The first step, in the autumn before planting, is to spray the site with an appropriate broad-spectrum herbicide (e.g. glyphosate) for controlling perennial weeds. The site should be sub-soiled if necessary, to remove compaction, then ploughed and left to over-winter. On light soils it may be more appropriate to spring plough. This will allow frost activity to break down the soil further. This may also help prevent 'ley' pests attacking the newly established plants, as any larvae or eggs already in the soil from the previous crop will have insufficient food over the winter to survive. In the following spring the site should be rotovated immediately prior to planting. This will not only improve establishment by aiding good root development but will also improve the effectiveness of any residual herbicides applied after planting. Planting can be conducted using semiautomatic potato planters, manure spreaders or bespoke planters. There is still some uncertainty as to which is the best planting method, because local site conditions can dramatically affect performance.

Picture 6 *Miscanthus mechanical planting with three-raw planter*

- **Harvesting**

The annual harvest of the stem material can be carried out between January and March using a number of different machines, depending on availability and requirement of the end market. For energy cropping, a baled product is the most desirable. However, this type of harvest involves two operations before the bale is produced and this can result in high biomass losses. The crop is first cut with a mower conditioner. Conditioning breaks up the rigid stems allowing accelerated moisture loss, and provides a light, rectangular windrow. This not only makes baling easier, but also helps in the drying of the material, by increasing the surface area and increasing air circulation in the swath. There are a number of different types of balers, each producing different bales, (e.g. rectangular, round and compact rolls), suitable for different scales of energy combustion. Large rectangular and round balers can produce bales with a dry matter density of between 120 and 160 kg/m3 and weighing between 250 and 600 kg. These balers generally have a capacity of 1 ha/hr. A critical factor for an energy crop is the moisture content at harvest. The drier the crop, the higher the energy yield and bale value. Moisture contents as low as 15% have been reported in southern Europe - although the lowest moisture content achieved in the UK has been around 20%, with the average closer to 50%. This may be partly because, in the UK, plants are still in the vegetative phase when the first frost induces die back. By conditioning and allowing it to dry in the field, the stem moisture content can be halved from 50% to 25%. Miscanthus has a net calorific value, on a dry basis, of 17 MJ/kg, with a 2.7% ash content. The energy value of 20 t of dry miscanthus would be equivalent to that of 12 t of coal.

Նկար 7. *Miscanthus-ի սուկյավորում*

- **Plantation erection and biomass production cost**

A rough cost brake down €/ha would be:

CAPEX	Eur
Planting material (cuttings)	1.600
Soil preparation	500[1]
TOTAL	2.100
OPEX (annually) Harvest, maintenance, land lease	200

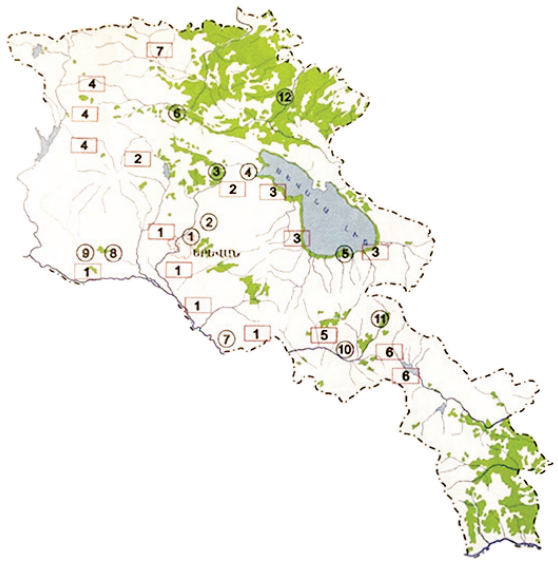
1 The cost is estimative and does not include works related to removal of removal of orchards, vineyards or similar works

3.3.3 Potential geography of energy crop plantations in Armenia

Estimations regarding the energy forests locations in Armenia have been done based on the existing experience with American poplar, mentioned above. The fast-growing crop has a cycle of 3-10 years, where at year 5 there is a chance to get 50t/ha if the recommended technology is used[1].

The potential locations, however, can be used to grow poplar, willow, miscanthus, canary reed, etc. to suit the energy needs. Geographically, testing fields have been established in 12 locations of the country as follows[2]:

1. Yerevan, botanical garden
2. Arinj, Flora Economy
3. Hrazdan, Tsakhkadzor
4. Sevan, botanical garden
5. Tsovinar, Sands of Shan
6. Vanadzor, botanical garden
7. Armash, saline lands
8. Yeghegnadzor, saline lands
9. Armavir
10. Vayk
11. Jermuk
12. Ijevan



Picture 8 *Potential of energy crops plantation in Armenia*

The estimated potential of additional energy forests is represented on picture 8 and is estimated to the following values:

- Ararat concave – 4800 hectares
- Aparan, Hrazdan – 750 hectares
- Sevan basin – 2000 hectares
- Shirak plateau – 2000 hectares
- Vayots Dzor – 300 hectares
- Syunik valleys – 1200 hectares
- Lori plateau – 250 hectares

Additional deep investigations should be conducted to seek for additional marginal and depleted land which cannot be used for other purposes, to assess their suitability for energy crops plantations. At this initial stage however, expanding the plantations of energy forests on more than 11,300 ha, indicated above, would generate sufficient biomass to replace 35% of the total current logwood demand.

3.4 CONCLUSIONS

Following official statistics data presented along this chapter as well as in the tables below, a total of 842,477 cubic meters of wood are consumed for energy purposes every year in Armenia. The energy embedded in this biomass equals to approximately 11.8 Tera Jules. Having assumed that the stoves and boilers used currently by households in Armenia have an average of 30% efficiency, 3.5 Tera Jules are really harnessed. It should be mentioned that 30% efficiency of stoves is a very optimistic figure and the real values would probably vary between 12-15%. For the purposes of this study, however, the value should be acceptable and taken as a reference because it supports the logic of drawing the most pessimistic scenario when designing the further path of this sector in Armenia.

1 Tsiveykova N. M. Samylin AA 2005

2 The testing fields are numbered in circles

Table 3 *Final energy consumption from logwood*

Province	Volume of consumed firewood (m^3)	Quantity of firewood, tons (average density 750[1] kg/m3)	Energy of the fuel, TJ (lower calorific value 18 MJ/kg)	Potential energy produced with the max. efficiency of stoves, up to 30%, TJ
Aragatsotn	86,478	64,859	1,206.37	362
Ararat Province	68,079	51,059	949.70	285
Armavir Province	98,921	74,191	1,379.95	414
Gegharkunik	43,502	32,627	606.85	182
Kotayk Province	75,820	56,865	1,057.69	317
Lori	220,757	165,568	3,079.56	923
Shirak	39,348	29,511	548.90	164
Syunik	62,082	46,562	866.04	259
Tavush	118,531	88,898	1,653.51	496
Vayots Dzor	28,959	21,719	403.98	121
TOTAL	842,477	631,858	11,752.55	3,525

An impressive quantity of biomass is still unharnessed and left in the fields to be burnt in Armenia. The statical data presents considerable potential in all the regions of the country. The total estimated 544 thousand tons of biomass contain approximative 2 thousand Tera Jules of energy.

Table 4 *Total residues suitable for biomass production, tons*

Province	Straw from cereal plants	Residual amounts of dry grass	Legumes, technical and vegetable crops	From orchards, berry orchards and vineyards	Total
Shirak	54,673	6,296	22,709	182	83,861
Gegharkunik	29,229	14,834	43,553	417	88,032
Lori	26,102	10,360	16,575	651	53,688
Syunik	21,333	8,552	7,111	819	37,814
Aragatsotn	20,720	9,885	7,406	2,458	40,468
Kotayk Province	15,434	3,940	7,936	1,232	28,542
Armavir Province	14,077	11,265	80,779	4,222	110,342
Ararat Province	11,240	10,408	47,656	3,568	72,873
Tavush	8,962	4,720	4,819	1,171	19,672
Vayots Dzor	2,030	2,902	2,049	912	7,893
Yerevan	2	107	273	427	809
Total	203,801	83,270	240,864	16,059	543,993

This quantity is, however, not sufficient to cover the current consumption of logwood. If used in the same stoves with low efficiency, the energy produced by all available biomass is 5 times lower than the energy from consuming logwood.

1 https://www.engineeringtoolbox.com/wood-density-d_40.html

Table 5 *Potential of energy to be produced from available biomass*

Source of biomass	Quant, tons	Useful for fuel production, tons	Calorific value, MJ/kg	Energy of the fuel, TJ	Potential energy produced with the max. efficiency of stoves, up to 30%, TJ
Straw from cereal plants	203,801	50,950	15	764	229
Residual amounts of dry grass	83,270	20,817	17	354	106
Legumes, technical and vegetable crops	240,864	60,216	15	903	271
From orchards, berry orchards and vineyards	16,059	15,256	18	275	82
Total	543,993	147,239		2,296	689

Similar situations are often in the countries where alternative sources of energy do not have a dominant position. Indeed, the biomass sector will be shade out by solar PV and biogas production, which are by far the champions in sunny Armenia. This, however, is not a reason to abandon the initiative to promote and develop the sector in the regions where it could solve environment and economic problems.

In this sense, the potential of Armenia to develop the biomass sector is more obvious in some regions through increasing the share of biomass collected from the field, processed for energy as well as introducing new efficient burning technologies to suit the locally existing fuel.

BIOMASS BASED **HEATING**

4. BIOMASS -BASED HEATING

4.1 MODERN SMALL-SCALE BIOMASS HEATING SOLUTIONS.

The European practice in this field is determined by modern high efficiency biomass boilers installed in the households as main source of heat. The systems managed in the EU countries are well established with constant supply of quality fuel, with modern biomass solutions which are almost as automatic as gas boilers. Briquette and pellet boilers are widespread solutions also in countries like Moldova, Ukraine and Belarus, which are in comparable to Armenia countries. There are different type of biomass heating solutions which are preferred by households, namely:

4.1.1 Logwood/Briquettes boilers

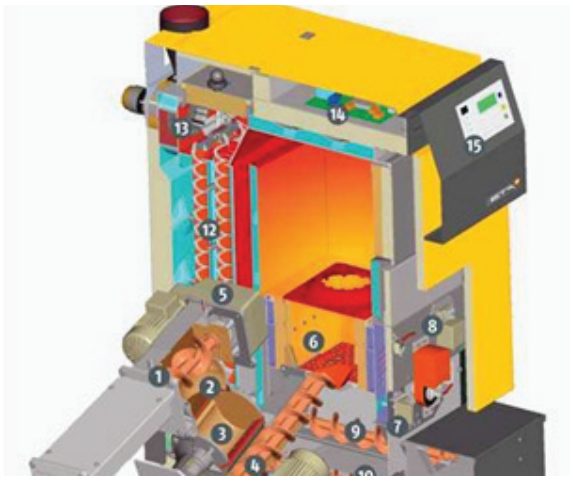
Logwood and briquettes-based heating systems are popular in rural and mountain areas. In several European countries are still the most common type of biomass boilers. There have been significant technological advances in heating systems during the past years, including:

- two-stage combustion with automatic ignition and fan;
- improved control systems;
- reduced heat losses.

Users convenience can be enhanced by large fuel hoppers and an appropriately sized accumulator tank, that is required. It allows the boiler to operate at nominal load and to avoid frequent ignition and shutdown.

4.1.2 Chips boilers

Wood chips heating systems are more common in rural and mountain areas, heating larger houses and farms. Advantages of using woodchips instead of firewood are automatic operation and much lower emissions because of the use of feed rate rather than air supply to control heat release rate. Wood chips boilers are often sited in basements, in free-standing heating containers (that combine boiler and storage) or in their own separate buildings (figure 2). Wood chips can be stored inside the building in a room close to the boiler or in storage facilities outside the building (e.g. silos, barns). The wood chips are transported to the boiler, often using a screw feed system. The size of the storage depends on the specific situation and should be correctly sized on the basis of energy demand.



Picture 9 *Example for chips fuel storage solutions*

4.1.3 Pellet boilers

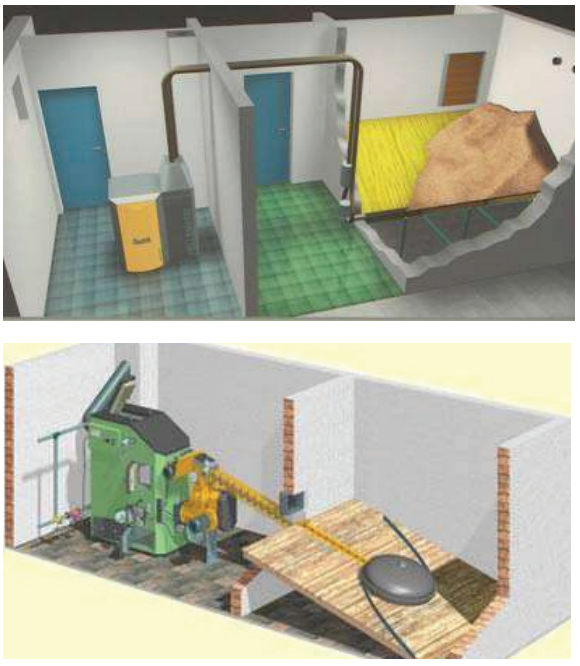
Pellet heating systems are installed primarily in urban and surrounding areas. Pellet boilers are usually sited in special boiler rooms, in the basement or in dedicated containers outside the house. The loose pellets are delivered in bulk by a pressurized tank truck and transferred into storage through a filler pipe. The pellet storage should be located not more than 30 meters from where the delivery truck will be operating. The walls and the ceilings of the storeroom and boiler room must be fireproof. Four main types of fuel storages are in the market:

- Storage rooms next/close to the boiler room (inside the building);
- Textile or steel tanks (inside or outside the building);
- Storage integrated into dedicated heating system containers (outside the buildings);
- Underground tanks (outside the buildings).

There are two types of fully automatic delivery systems that transfer pellets from storage into the boiler, presented on the picture below:

- Screw systems: suitable if boiler and storage rooms/tanks are located next to each other;
- Suction pump system: the solution if the storage and boiler room are separated.

Picture 10 *Pellet boiler functioning principle*



Picture 11 *Types of fully automatic fuel delivery systems that transfer pellets into the boiler*

4.1.4 Pellet stoves

Special kinds of stoves have been constructed to combust only pelletized material. Pellet stoves are very popular and installed both in urban and rural areas. The stove components are much more sophisticated then the firewood stoves. An electric fan controls the combustion process by varying the supply of combustion air. This results in low CO and CxHy emissions.

Pellet stoves are typically provided with small fuel storage, fuel feeder, combustion air blower, burner shell and a flue gas discharge system. They are equipped with a rather extensive control system. The fuel hopper is filled from the top and a device transfer the pellets from the hopper

to the heating chamber on a controlled and automatic system using an internal thermostat to gauge the heat and when more pellets are needed to be added. Then, air from the room is sucked in from a built-in fan which is then transferred through the heating chamber. The hot air is then distributed back into the room or through your vent system of your house.

Pellet stoves could be air or water heating systems, mainly bought to produce only heat in a single room or in an integrated heating system.

4.1.5 Briquette stoves

This kind of stoves were constructed to combust briquettes and logwood. They are poplar and installed in the rural areas where the stove has a doble use, as heating sources and as a cooking device. In some advanced versions of the stoves, an electric fan is controlling the combustion process.

The briquette stoves are usually equipped with a control unit but require manual loading. Similar to pellet stoves the briquette stoves can be air or water heating systems. In some advanced versions, there is a possibility of combined air and water supply.

4.2 PRICES OF HEATING SOLUTIONS

4.2.1 Biomass boilers

The prices for boilers as well as stoves vary. There are multiple factors affecting the final prices of such solutions. The most important are however the level of efficiency, the number or type of fuels designed to work with as well as the number of operation hours on one loading. There might be additional parameters affecting the final price of the boiler/stove, but usually the above mentioned are the ones to be considered when deciding over the procurement of a heating solution.

Assuming a 20kW capacity of the boiler, the top tier - expensive heating systems (3 500 euro and higher) are the boilers equipped with features that ensure an autonomous functioning up to 1-2 weeks. Self-cleaning is a function that is usually included in the standard offer. Such boilers may operate on different fuel offering the possibility to feed the boilers with briquettes and/or pellets, depending on the fuel availability. This might be very convenient if the fuel supply is not yet secure on the market. The standard efficiency of such boilers starts with 82% and up. Boilers ranges produced by Atmos and Rojek Czech Republic, Ferolli and D'Alessandro from Italy are a couple of companies offering such solutions.

Galmet, DREWMET, and Moderator from *Poland*, BIOKAITRA, *Latvia* are examples of boilers in the middle price tier ranging from 2 000 to 3500 Euro. These types of boilers are usually one type fuel burners, with manual cleaning, but automatic feeding, in case of pellets. Their level of autonomy is lower comparing to the more expensive units.

The low-price tier is represented by boilers with efficiency below 80% with manual feeding as well as cleaning. The autonomy of work is usually ranging 1-2 days. These are the cheapest heating solutions on biomass, and they can be found at less than 2 000 Euro on the European market.

The table below represent a few brands representing different price categories for biomass boilers.

Table 6 *Average prices for boilers produced in the region, EUR*

	Producer	Origin	Average Price (Euro)
	Atmos, Czech Republic	Provides large variety of heating systems both on biomass and traditional fuel.	4 534
	Rojek, Czech Republic	The company is present in industry for 90 years. Specialises on production of boilers that work on wood pellets and solid fuels. Combined fuel heating systems can be a suitable solution for initial stages of project implementation.	4 350
	Ferroli, Italy	The company is producing a large range of models of boilers and additional equipment both for domestic and industrial heating. Almost all models are able to operate both on pellets and briquettes.	3 600
	Galmet, Poland	The company is specialized on production of heating systems that work on briquettes and pellets. The range of products dedicated to households are ranging 16-30 kW capacity.	3 370
	Drewmet, Poland	The brand is positioned as producer of big household heating systems (17-24kW). The boilers are suited to burn both briquettes and pellets, in some models both options are available in one solution.	3 340
	Moderator, Poland	The company operate on the market of heating solutions for almost 40 years, being one of the oldest in this category. It offers a wide range of heating solutions on different type of fuels.	2 970
	Koteko, Ukraine	The cheapest heating solution from the presented brands. The average nominal efficiency is up to 80%.	1 380

The list of products is just for orientation and does not represent a promotion. The sole purpose of compiling the list was to list the price categories and main features of boilers that exist on the market today.

4.2.2 Biomass heating and cooking stoves

The stoves are simpler solutions, usually preferred in rural areas where the multipurpose use is one of the selection criteria for such type of equipment. The reason behind lower demand for stoves comparing to biomass boilers is they are less efficient. The benefit of being multifunctional is much appreciated in the rural areas, where heating and cooking seems to be done simultaneously. Another benefit in favor of such solutions is the price, which for basic and simplistic solutions is considerably lower comparing to more sophisticated biomass boilers. Installation is also easier - it does not require any connections to an internal piping system within the household.

There are different types of equipment sold globally. The most sophisticated being equipped with water jackets, electric fan for burning control, thermometer, etc. These solutions can generate hot air as well as heat, distributed through internal piping systems.

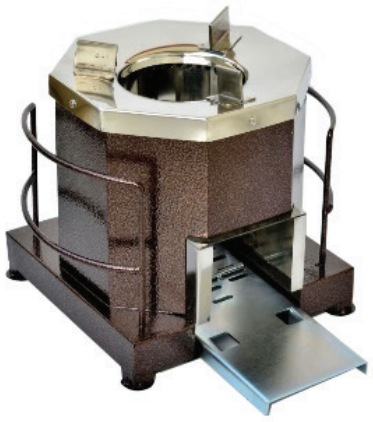
The prices for such solutions are, however, not so different comparing to boilers. Different producers are offering solutions ranging from 700 to 2000 USD. Pellets and briquettes fed models are available and can be selected based on the preferences of the consumer.

This type of stoves can operate in a long burning being resistant to high temperatures. This particular solution is built to heat up to 150 square meters. The list price for such solution is around 170-180 Euro. The advantage of this solution comparing to the ZVEZDA model is the special custom regime between Armenia and Russia, which enables the import of similar solutions without any additional duties.

The most simplistic models do not have any features and are solutions ranging from 50-150 USD. These are usually open fire solution, without any track of efficiency and represent a fire security risk if used in house. Also, there is high probability, this type of stoves may damageg the health of household members because of smoke and fine particles eliminated during their use.

Picture 12 *ZVEZDA classic gfs ceramic, Bulgaria*

Picture 13 *Конвектика, Ставр 9 stove, Russia*



Picture 14 *Biomass cooking stove*

BIOMASS
FUEL
PRODUCTION

5 BIOMASS FUEL PRODUCTION

Biomass in its original form is difficult to successfully use as a fuel in large-scale applications because it is bulky, wet, and dispersed. Basically, biomass densification represents a set of technologies for the conversion of biomass into a fuel. The technology is also known as briquetting and it improves the handling characteristics of the materials for transport, storing etc. This technology can help in expanding the use of biomass in energy production, since densification improve the volumetric calorific value of a fuel, reduces cost of transport and can help in improving the fuel situation in rural areas. These technologies are also known as pelleting, briquetting, or agglomeration, which improves the handling characteristics of the materials for transport, storage, etc. Pelleting and briquetting have been applied for many years in several countries. William Smith was the first to be issued a United States patent (1880) for biomass densification. Using a steam hammer (at 66°C), Smit compacted waste from sawmills.

Conventional processes for biomass densification can be classified into baling, pelletization, extrusion, and briquetting, which are conducted using a bailer, pelletizer, screw press, piston or a roller press. Pelletization and briquetting are the most common processes used for biomass densification for solid fuel applications. These high-pressure compaction technologies, also called "binderless" technologies, are usually carried out using either a screw press or a piston press (Sokhansanj et al. 2005). In a screw press, the biomass is extruded continuously through a heated, tapered die. The briquette quality and production process of a screw press are superior to piston press technology. However, comparing wear of parts in a piston press, like a ram and die, to wear observed in a screw press shows that the screw press parts require more maintenance. The central hole incorporated into the densified logs produced by a screw press helps achieve uniform and efficient combustion, and the resulting logs can be carbonized more quickly due to better heat transfer.

The main advantages of biomass densification for combustion are:

- simplified mechanical handling and feeding
- uniform combustion in boilers
- reduced dust production
- reduced possibility of spontaneous combustion in storage
- simplified storage and handling infrastructure, lowering capital requirements at the combustion plant
- reduced cost of transportation due to increased energy density

The major disadvantage to biomass densification technologies is the excessive cost associated with some of the densification processes, such as:

5.1 PRELIMINARY TREATMENT OF BIOMASS

Prior to biomass densification, pre-treatments may be required to optimize the energy content and bulk density of the product. Pre-treatment can include:

- chop length/grinding
- drying to required moisture content
- application of a binding agent
- steaming
- torrefaction

5.1.1 Chop Length/Grinding

Each densification process requires specific chop length and/or grinding to achieve:

- lower energy use in the densification process
- denser products
- a decrease in breakage of the outcome product

5.1.2 Drying

Low moisture results in improved density and durability of the fuel (Shaw and Tabil 2007). For most biomass densification processes, the optimum moisture content is in the range of 8%–20% (wet basis) (Kaliyan and Morey 2009). Most compaction techniques require a small amount of moisture to "soften" the biomass for compaction. Above the optimum moisture level, the strength and durability of the densified biomass are decreased.

5.2 MECHANICAL DENSIFICATION. BRIQUETTING

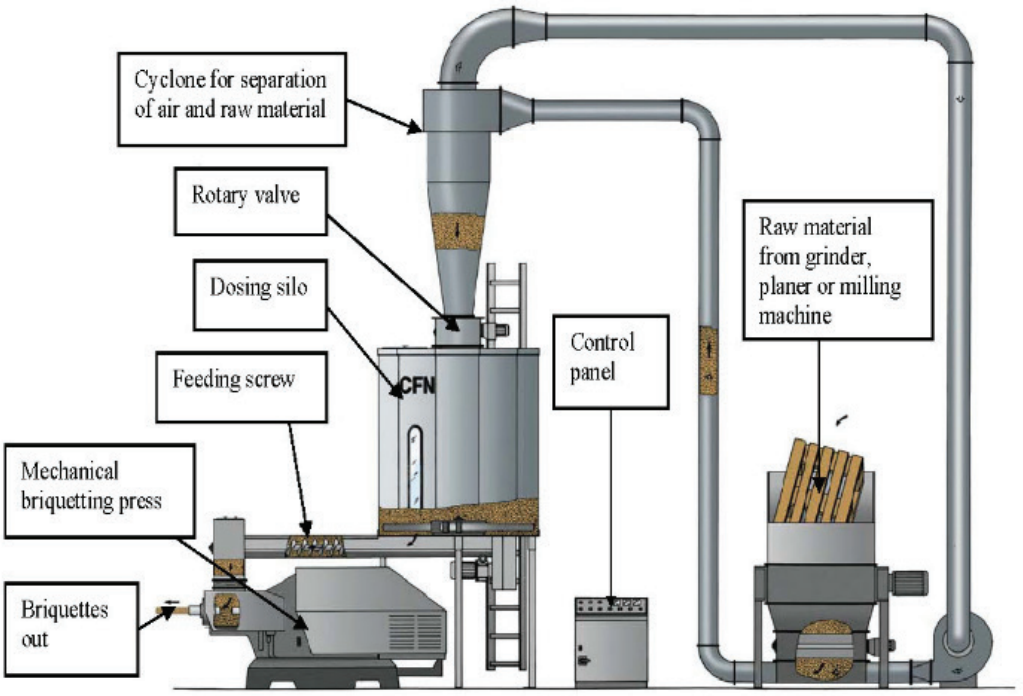
Briquettes are generally 50-80 mm diameter and 150 mm length sawdust cylinders compressed at a high temperature, with a moisture content ranging between 10 to 20%. Other shapes, rectangular or prismatic, are also frequent, depending on the manufacturer. In some cases, they have holes to improve their combustion. Densification of loose and smaller biomass waste using a briquette press is a viable and attractive solution to utilize biomass for fuel applications. Briquetting is usually performed using hydraulic or mechanical presses. The briquettes' densities generally range from 900 to 1600 kg/m3. The biofuel briquette is a clean and green fuel that can ideally be used in furnaces, boilers, or open fires. In the biomass briquetting process, the material is compressed under high pressure and temperature. During briquetting the biomass particles self-bond to form a briquette due to thermoplastic flow. Lignin, which is a natural binder, is made available from elevated temperatures and pressures resulting in the formation of high-density briquettes.

5.2.1 Mechanical Piston Press

Mechanical piston presses are typically used for large-scale production, ranging from 200 to 2,500 kg/hr (Figure 8). The mechanical press is designed as an eccentric press. A continuously rotating eccentric, connected to a plunger, presses the raw material through a conic die.

Picture 16 *Mechanical press*

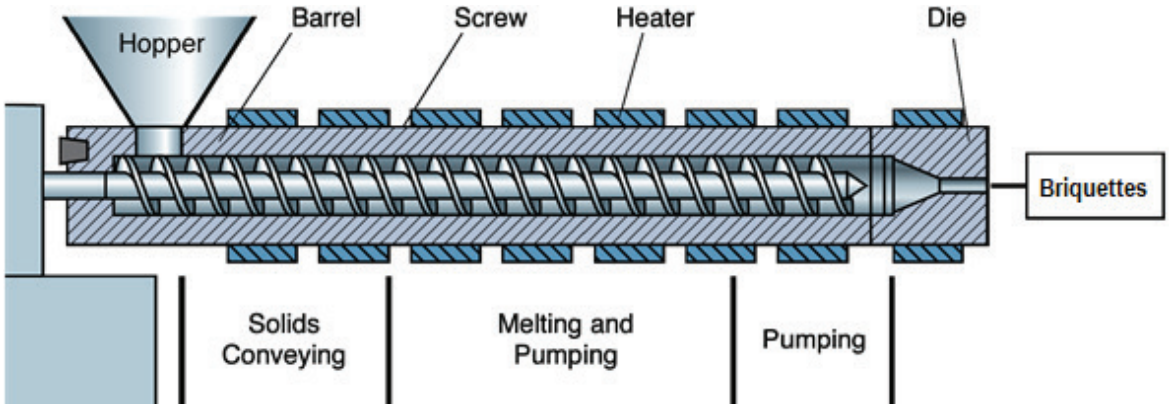
In mechanical presses, the counter pressure required can only be adjusted by mounting a die with a different conicity (www.cfnielsen.com). The mechanical press is driven by electric motors instead of a hydraulic motor. Energy loss in the machine is limited, and the output in relation to power consumption is optimal. The operating life of a mechanical press is considerably longer than hydraulic presses. Generally, a mechanical press gives a better return on investment than a hydraulic press. The process flow for continuous briquetting using a mechanical piston-type press is given in Figure 15.



Picture 15 *Continuous piston-type briquetting production line*

5.2.2 Screw Compaction or Extrusion

The aim of compaction using an extruder is to bring the smaller particles closer so that the forces acting between them become stronger, providing more strength to the densified bulk material. During extrusion, the material moves from the feed port, with the help of a rotating screw, through the barrel and against a die, resulting in significant pressure gradient and friction due to biomass shearing. The combined effects of wall friction at the barrel, internal friction in the material, and high rotational speed (~600 rpm) of the screw, increase the temperature in the closed system and heat the biomass. This heated biomass is forced through the extrusion die to form the briquettes or pellets with the required shape. If the die is shaped, the biomass is further compacted. If the heat generated within the system is not sufficient for the material to reach a pseudo-plastic state for smooth extrusion, heat is provided to the extruders from outside either using band or tape heaters. Figure 9 shows the typical extruder, with different zones for processing of biomass.[1]



Picture 17 *Extruder for biomass processing*

Processing of biomass using screw compaction involves the following mechanisms[2]

1. Before reaching the compression zone (a zone usually formed by tapering of the barrel), the biomass is partially compressed to pack the ground biomass. It is during this first stage that the maximum energy is required to overcome particle friction.

2. Once the biomass is in the compression zone, the material becomes relatively soft due to high temperature (200–250°C), and during this heating, the material loses its elastic nature, which results in an increased area of inter-particle contact. At this stage, local bridges are formed when the particles come closer, and the interlocking of particles may also result. During its passage through the compression zone, the biomass absorbs energy from friction so that it may be heated and mixed uniformly through its mass.

3. In the third stage, the biomass enters the tapered die, where the moisture is further evaporated due to the prevailing temperature of 280°C, helping to better moisten the biomass and increase the compression on the material.

4. In the final stage, the removal of steam and compaction take place simultaneously and the pressure throughout the material normalizes, resulting in a uniform extruded log.

The following are the merits of screw compaction:

- ✓ The output from a screw press is continuous, and the briquettes are more uniform in size.
- ✓ The outer surface of the briquette is partially carbonized, which can help facilitate ignition and combustion. This also protects the briquettes from ambient moisture.

1 http://matse1.mse.uiuc.edu/polymers/prin.html

2 Grover and Mishra, 1996

- ✓ A concentric hole formed in the briquettes helps for better combustion because of air circulation during burning.
- ✓ The machine runs smoothly without any shock load.
- ✓ The machine parts and the oil used in the machine are free of dust or raw material contamination.

Picture 18 *Heat log produced using an extrusion press*

One demerit of screw compaction is that the power requirement of the machine is high compared to that of the piston press.

Figure 10 illustrates the typical biomass heat logs prepared using an extrusion press. Specifications of typical biomass heat logs are given in the table below.

5.3 HYDRAULIC PISTON PUMP

Hydraulic piston presses are commonly used as briquetting machines for densification of biomass. The energy to the piston is transmitted from an electric motor via a high-pressure hydraulic system. The output of a hydraulic press is lower since the movement of the cylinder is slower compared to mechanical processes. The briquettes have a bulk density lower than 1000 kg/m^3 because pressure is limited to 40–135 kg/h. However, these machines can tolerate higher moisture contents than the usually accepted 15% for mechanical piston presses[1]. To improve the production capacity, some continuous briquetting presses are available commercially. Figure 9 and Figure 10 show a hydraulic press and the briquettes produced from straw using a hydraulic press.

Picture 19 *Straw briquettes from a hydraulic press*

Picture 20 *Hydraulic press*

1 Source: www.cfnielsen.com

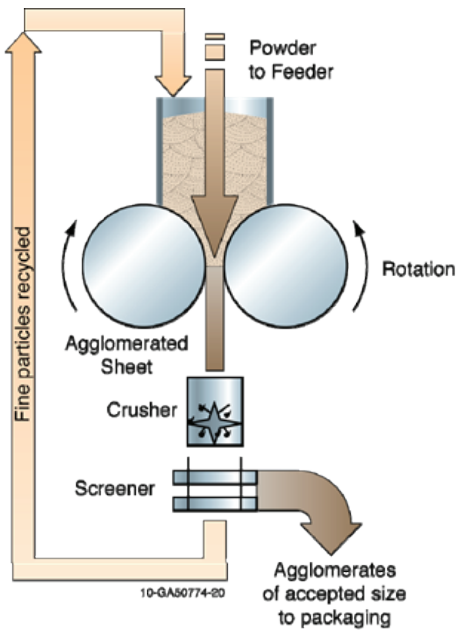
5.4 BRIQUETTING EQUIPMENT SUPPLIERS

Company	Briquetting technology	Raw material type	Productivity, t/h
Ekobrik, Belarus, 220012 Minsk, Surganova str., 20 -1. Tel: (37529) 651-03-73 Fax: (37517) 227-53-48 E-mail: brikk@yandex.ru	Screw drive	Wood residues	150-800
DIPIU', Italy, Via dell'Innovazione, 11 - 36042 Breganze (VI) Tel +39 0445 300709 Email: info@di-piu.com Web: http://www.di-piu.com	Piston press	Wood residues, straw	700-1300
COMERC, Poland, UL. GDYŃSKA 31/33, 61-016 POZNAŃ, POLSKA TEL.+48 61 878 65 61 office@comerc.pl slawek@comerc.pl www.comerc.pl	Hydraulic press	Wood residues, straw	300-700
C. F. Nielsen A/S, Denmark, Solbjergvej 19, DK-9574 Baelum Tel: +45 98 33 74 00 http://www.cfnielsen.com	Hydraulic and piston presses	Wood residues, straw	80-1800
GEM-EKO, Poland, Białachówko 2A, 83-210 Zblewo Tel: (+48) 507 015 014 E-mail: biuro@gem-eko.pl http://www.gem-eko.pl	Hydraulic press	Wood residues, straw	300-500
RUF-Brikett, Germany, Hausener Str. 101, 86874 Zaisertshofen +49 - 8268 - 9090-20 http://www.brikettieren.de	Hydraulic press	Wood residues, straw	100-1500
Briklis, Czech Republic Briklis, spol. s r.o., Malšice 335 391 75 Phone : +420 381 278 050 +420 381 278 731 email: info@briklis.cz Web: www.briklis.cz	Hydraulic and piston presses.	Wood residues, straw	200 -800
Warfama SA, Poland, ul. Fabryczna 21, 11-040 Dobre Miasto Tel. +48 089 615 34 00 Tel. +48 089 615 36 00 e-mail: warfama@warfama.pl http://warfama.pl	Piston press	Straw	1200-1600
ASKET, Poland, ul. Forteczna 12a, 61-362 Poznań tel. +48 61 877 05 05 e-mail: biuro@asket.pl http://www.asket.pl	Screw drive	Straw	300-500-1000
ООО «ПК «Транстрейд Украина», Ukraine, Tel /fax: +38044-220-14-78 E:mail: office@transtrade.com.ua http://briket.net.ua	Screw drive	Wood residues	350-800

Company	Briquetting technology	Raw material type	Productivity, t/h
Votecs, Germany, Robert-Mayer-Strasse 5, 74360 Ilsfeld. Tel: +49 (0) 7191 36 98 996 / +49 (0) 7191 36 98 997 · E-mail: info@votecs.de Web: www.votecs.de	Hydraulic press	Wood residues	40-200
WEIMA Poland, Poland, Legacz 1, 05-304 Stanisławów Telefon: +48 (0)25 7525252 weima@weima.pl; http://www.weima.com	Hydraulic press	Wood residues, straw	70-400
CO.MA.FER. MACCHINE S.p.a, Italy, Via de Gasperi Angolo Via Roma 25060 Collebeato- Brescia Italy Tel.: (0039) 030-2510405 E-mail: infomac@comafer.it Web: http://www.comafermacchine.it	Hydraulic press	Wood residues	70-350
ООО Черкассы Элеватор Маш, Ukraine, 7a Khimikov avenue, Cherkassy, Ukraine Tel.: +38 0472 642052, 642418, 642288, 326337 E-mail: bronto@bronto.ua Web: http://www.bronto.ua	Screw drive and hydraulic presses	Wood residues, straw	350-500
ООО «СПиКо» , Russia, 180680, Pskov, Industrialnaya str. 9/1. tel/fax : +7 8112 52 07 07 E-mail: zavod@sp-co.ru http://www.sp-co.ru/	Screw drive press	Wood residues, straw	500-1500

5.5 MECHANICAL DENSIFICATION. PELLETIZING

Pellets are the result of a process which is closely related to the briquetting processes described above. The main difference is that the dies have smaller diameters (usually up to approx. 30 mm) and each machine has a number of dies arranged as holes bored in a thick steel disk or ring. The material is forced into the dies by means of rollers (normally two or three) moving over the surface on which the raw material is distributed. Pellets are very high in density. They are easier to manage than other densified biomass products, since infrastructure for grain handling is used for pellets. Pellets are formed by an extrusion process, using a piston press, where finely ground biomass material is forced through round or square cross-sectional dies and cut to a desired length. The standard shape of a biomass pellet is a cylinder, having a length smaller than 38 mm and a diameter around 7 mm. Although uniform in shape, pellets are easily broken during handling. Different grades of pellets vary in energy and ash content.

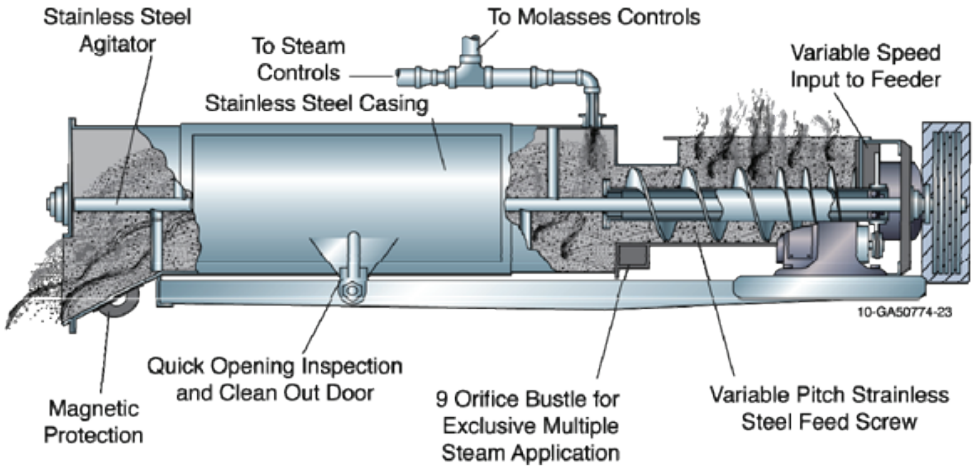


Picture 21 *Roller press mill*

Pellet presses consist of two types: the ring die and the flat die. In both the ring- and flat-die machines, the die remains stationary, and the rollers rotate. Some rotating die pellet mills are available in which the rollers remain stationary during the production process.

In principle, the incoming feed is delivered uniformly into the conditioner for the controlled addition of steam and/or molasses. This unit operation helps improve binding of the material during pelletizing. Most pellet mills now have, mounted above the main unit, one or more conditioning units where liquids such as water and molasses can be added to improve pelletability. Various components of a screw conditioner normally used in the pellet mill are shown in Picture 16.

The feed from the conditioner is discharged over a permanent magnet and into a feed spout leading to the pelleting die. The added steam softens the feed and partially gelatinizes the starch content to create more durable pellets. Inter-elevator flights in the die cover feed the mash evenly to each roller, and the feed distributor flights distribute the material across the face of the die. Cut-off knives mounted on the swing cover cut the pellets as they are extruded from the die, allowing the pellets to fall through the discharge opening in the swing door.



Picture 22 *Component of a screw conditioner. Richard H. Leaver, Andritz Sprout*

5.6 PELLETIZING EQUIPMENT SUPPLIERS:

Company	Contacts	Web/email
CPM/Europe BV Diestelweg 89 NL-1031 HD AMSTERDAM	Tel: +31 20 494 6111	http://www.cpmeurope.nl/
Amandus Kahl Dieselstraße 5 D-21465 Reinbek	Tel. +7 495 6443248 Tel: +49(40)727 71-0, Fax: +49(40)727 71-100	info@amandus-kahl-group.de http://www.amandus-kahl-group.de/kahl_gruppe/de/home/
Buhler AG Representative Office Austria, Manchner Bundesstrasse 142,5020 Salzburg, Austria	Tel: + 43 (662) 43 01 21 20, Fax: + 43 (662) 43 01 21 21	http://www.buhlergroup.com/global/en/home.htm#.UgOVYNKTQmk
UMP Antakalnio II k. Ukmergės pst. LT-20101 Ukmergės raj. Savivaldybė Lietuva	Tel. +370 340 58782	http://www.briquette.lt/
Muench-Edelstahl GmbH Germany, Hilden 40721, Weststrasse 26 Munch	Tel. +49 2103 58996	http://www.muench-edelstahl-gmbh.de/
Голдэн Трэйд0 4655 Украина, г. Киев, ул. Корабельная, 6	Tel. +38 (044) 229-62-88	http://www.goldentrade.com.ua/

Company	Contacts	Web/email
PRODESA Prodesa Medioambiente S.L. Ciudad del Transporte Edificio Somport, Esc. 3 Ofi. 125 50820 Zaragoza, Spain	Tel.: +34-976-459477	http://www.prodesa.net/default.asp?id=125&idioma=2
Экодрев -Тверь г. Тверь, п. Васильевский Мох, ул. Ленина, д. 3	Tel. +7 4822 382-180	http://www.ekodrev.ru/tehnologii_bio_energetiki.html
JSC "Universalūs Medžio Produktai" (UMP) vill. Antakalnio II,20101 Ukmerge,Lithuania	Tel. +370 340 58782; Mob. +37061870295 Tel. +370 340 63620;	http://www.briquette.lt/ http://www.ump.lt/
ECOWORXX GmbH Kreuzkrug 44, 31604 Raddestorf, D-31604 Raddestorf Gernany	Tel. +49 (0) 57 65- 94 26 68	http://www.ecoworxx.com/index.html
ANDRITZ AG Stattegger Strasse 18, 8045, Graz, Austria	Tel: +43 31 669 020	welcome@andritz.com, https://www.andritz.com/group-en
ООО «СПиКо» \Л••Г\, г. Псков, ул. Индустриальная \/Ч.	Tel. +7 8112 292 307 Tel. +7 8112 292 301,	m1@sp-co.ru, http://www.sp-co.ru/

SUSTAINABILITY OF BIOMASS **FUEL** PRODUCTION

6 SUSTAINABILITY OF BIOMASS FUEL PRODUCTION

The quality of biomass briquettes and pellets depends on the raw materials and the briquetting process. The desired qualities for briquettes as fuel include good combustion, stability and durability in storage and in handling (including transportation), and safety to the environment when combusted. Combustion and environmental safety are dependent mostly on the nature of the raw material. This nature includes the structure (e.g., size, fibrous, non-fibrous, etc.), chemical (e.g., lignin-cellulose content), physical (e.g., material particle size, density, and moisture content), and purity (e.g., trace of element (sulfur), etc.). Combustion is measured by parameters such as calorific value, ease of ignition, and ash content, while environmental concern is measured by the toxic emissions during combustion.

The biomass compacting process, on the other hand, determines the durability and stability of the fuel. Compressive strength, abrasion resistance, impact resistance, moisture absorption, and density are basically the parameters that determines durability and stability. They are considered the most important quality parameters of densified biomass. The quality of solid biomass fuel is characterized in terms of physical, mechanical, chemical, and thermal properties, depending on the measured parameters. It is also indicative of the effectiveness of the densification process and influences their ability to endure certain impacts because of handling, storage, and transportation. Table 7 presents parameters and tests standards used to measure briquette quality.

Table 7 *Recommended values for (W) woody and (NW) non-woody biomass fuel*

Parameter	Guiding Value		Test Standards
	Briquettes	Pellets	
Moisture content	<12% - <15%	<11% - <13%	ISO18134-2[1]
Density	W >0.9 gcm^3, >1.0 gcm^3 NW >0.6 gcm^3, >0.9 gcm^3	0.6 – 0.7 gcm^3	ISO 18847[2] ASTM D2395-17[3]
Compressive strength	1.0 MPa	1.51 MPa	
Durability	95%	95%	ISO 17831-2[4]
Calorific value	W>14.9 MJ/kg, >15.5 MJ/kg NW>14.5 MJ/kg, >14.5 MJ/kg	W 19.9 MJ.kg NW 18 MJ/kg	ISO 18125[5]
Ash content	W <1.0%, <3.0% NW <6.0%, <10.0%	NW 3.3–12% W<0.7%	ISO 18122[6]
Carbon (C)	48-50%		ISO 16948
Hydrogen(H)	6.2%		
Nitrogen (N)	W <0.3% - <1.0% NW <1.5%, <2.0%		
Sulphur (S)	W <0.04%- <0.05%. NW <0.2% - <0.3%.		ISO 16994

1 ISO 18134-2, 2017. *Solid Biofuels—Determination of Moisture Content—Oven Dry Method—Part. 2: Total Moisture—Simplified Method*; ISO: Geneva, Switzerland, 2017

2 ISO 18847, 2016. *Solid Biofuels—Determination of Particle Density of Pellets and Briquettes*; ISO: Geneva, Switzerland, 2016

3 ASTM D2395-17. *Standard Test. Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials*; ASTM International: West Conshohocken, PA, USA, 2017

4 ISO 17831-2, 2015. *Solid Biofuels—Determination of Mechanical Durability of Pellets and Briquettes*; ISO: Geneva, Switzerland, 2015

5 ISO 18125, 2017. *Solid Biofuels—Determination of Calorific Value*; ISO: Geneva, Switzerland, 2017

6 ISO 18122, 2015. *Solid Biofuels—Determination of Ash Content*; ISO: Geneva, Switzerland, 2015

Moisture content is evaluated to assess possible changes in the physical conditions of briquettes during storage and transport. It also could influence mechanical strength, durability and thermal efficiency.

Density is determined by the mass of particles per unit volume of a sample solid fuel. It influences transportation cost and energy density.

Water resistance is determined by the rate at which briquettes can withstand degeneration in humidity or water exposure. The ability of briquette to resist moisture penetration when exposed which could affect combustion and durability in storage.

Compressive strength determines the maximum crushing loads a briquette can withstand before cracking or breaking. Make briquettes safe to store, transported without breaking

Durability determines the rate at which briquettes can withstand degeneration when handled and transported. The test simulates mechanical or pneumatic handling which shows briquettes ability to resist abrasion.

Calorific value determines the amount of thermal energy in the combustion of one kilogram of briquette. This indicates the energy recovery potential of biomass during thermos-chemical conversion

Ash content determines the percentage ash content the fuel may produce after combustion. Ash content in the biomass briquettes or pellets causes increase in the combustion remnant in form of ash which lowers the heating effect of the fuel and may cause slagging

Level of Carbon (C), Hydrogen(H), Nitrogen (N) determines combustion properties of biomass fuel and undesirable amount of emission i.e., NOx. These elements suggestive of the fuel properties of briquettes. They influence combustion.

Level of Sulphur (S) determines the amount of undesirable emissions, i.e., SOx . Sulfur is oxidized and converted to SO2 gas during combustion in furnaces. Sulfur pollutants are harmful to the environment.

6.1 QUALITY TESTING EQUIPMENT FOR BIOMASS

Quality control and supervision represents a key element to a sustainable market development. A quality certification mechanism is required to ensure the security of the market. Nascent markets tend to deviate from quality development path, gravitating around the price competitiveness, which might jeopardize the trust of using biomass. Quality control and supervision is therefore a paramount function that should be established from early stages of market development.

Technically, the control, supervision and certification functions will be exercised by a specialized institution, such as laboratories, scientific institutes with experience in testing quality of similar goods and commodities.

The table below presents the list of measurement equipment required for a specialized laboratory to prove the parameters of biomass fuel.

Table 8 *Fuel parameters and equipment required for testings*

Parameter	Measurement Equipment
Moisture content	Thermogravimetric analyzer, drying oven with temperature range of 105 ± 2 ◦C, Digital weighing scale
Density	Digital weighing scale, digital or manual caliper
Water resistance	Digital weighing scale, digital or manual caliper
Shatter index	Digital weighing scale, meter rule, steel plate, sieve
Compressive strength	Universal Testing Machine
Durability	Durability tester
Calorific value	Bomb calorimeter
Ash content	Furnace with a temperature range of 550 ± 10 ◦C
Volatile matter	Furnace with a temperature range of 900 ± 10 ◦C

Parameter	Measurement Equipment
Carbon (C)	Element analyzer
Hydrogen(H)	
Nitrogen (N)	
Sulphur (S)	Atomic emission spectrometer

6.2 BIOMASS POLLUTANTS EMISSIONS

The pollutant emissions from biomass can be classified in two groups. The first group consists of the unburnt pollutants, which are mainly influenced by the combustion equipment and process. The other group consists of pollutants which are mainly influenced by the fuel properties.

If the combustion is incomplete, due to factors such as local low temperatures, poor mixing with oxygen, moisture content, too short residence time and etc., products such as CO, CxHy, HC, tar, PAH, soot and char particles are released. These substances are emitted from all biomass fuels, but the released amount depends on furnace design, fuel used and/or operating conditions.

NOx production during the combustion of fossil fuels is already well known and in case of coal combustion arises from the main mechanism: thermal-NOx (from high temperature oxidation and atmospheric N2), prompt-NOx (from the reaction of fuel derivative radicals and atmospheric N2) and fuel-NOx (from oxidation of nitrogen chemically bound in the fuel). The contribution of the first two, whose mechanism route is well known, in total amount of NOx produced in most biomass combustion systems are below 30%.

The majority of the NOx in biomass combustion is produced from the fuel bound nitrogen which can be present in biomass as inorganic nitrate and ammonium ion, amino compounds (includes proteinaceous fraction), heterocyclic purines, pyrimidines and pyrroles.

Non-conventional biomass usually has high content of alkali oxides and salts which consequently contribute to the low ash melting sintering temperature. These low melting temperatures of some types of biomass pose serious burning appliances operation problems which includes agglomeration, fouling, slagging and in some cases corrosion of heat exchanger surfaces. Therefore, a careful analysis of ash melting properties should be the first step in choosing the adequate combustion system and combustion conditions for a given biomass.

Typically, agricultural residues and energy crops have higher K2O content compared to conventional biomass or coal. This is manly attributed to the use of fertilizers in agricultural industry. Since the ash consists of a mixture of different inorganic compounds, it has no well-defined melting point and the melting process takes place over a wide temperature range starting with the initial deformation temperature. It is seen that straws from rye, oat and barley, with high contents of K2O have much lower melting temperatures compared to the wheat straw, which have lower content of K2O.

Solutions to this problem exist and should be implemented carefully while piloting the first burning solutions in Armenia.

6.3 SUSTAINABILITY STANDARDS FOR BIOMASS

To respond to potential environment challenges that might be caused by the extensive use of biomass, standards should be adopted to clearly pave the road to the implementation of biomass for energy. One of the main goals of switching to alternative source of energy is to ensure that use of biomass for energy purposes goes hand in hand with the conservation of biodiversity and local environment, because biomass production and consumption may create additional environmental pressures, such as on biodiversity, soil and water resources. To sustainably develop it, the following could be used as guiding principles:

Eligibility of sources.

Eligible biomass comprises:

1. Woody biomass (forests and plantation wood; wood processing industry, by-products and residues; used wood, blends and mixtures)
2. Herbaceous biomass (agriculture and horticulture herb including cereal crops, grasses, oil seed crops, root crops, legume crops, flowers and landscape management herbaceous biomass; herb processing industry, by-products and residues; blends and mixtures)
3. Fruit biomass (orchard and horticulture fruit; fruit processing industry, by- products and residues, blends and mixtures)
4. Blends and mixtures as well as animal excrements, e.g. manure or chicken litter etc. (but no animal body or parts of it)

GMO

The use of genetically modified organisms (GMO, agricultural crops as well as trees) for energy production is not permitted

Energy crops

Energy crops shall **not** be produced on arable land which has been gained by conversion of pasture or grassland. Short rotation tree plantations should not be established on forest areas or on arable land which has been gained by conversion of pasture or grassland

Quality of raw material

Biomass from dedicated cultivation on arable land need to comply with local quality standards to be further used for biomass fuel production.

No useless residues from agriculture

All financial and technical support is granted only if sustainable agricultural principles are in place. No state subsidy is provided to farmers unless the proof of residues utilization.

CURRENT PRODUCTION AND CONSUMPTION **OF BIOMASS FUEL** IN ARMENIA

7 CURRENT PRODUCTION AND CONSUMPTION OF BIOMASS FUEL IN ARMENIA

Biomass fuel production is one of the most promising areas of renewable energy in Armenia. Though it is in the early stages of development, there is a good understanding of the production technologies and means of use. Another trigger for the interest is the low level of rural areas gasification and fuel poverty.

Due to the support of international development partners small-scale pilot projects[1] several productions of solid biofuels have been financed in the rural communities of the country. The preliminary achieved results show a great interest for the biomass processing activity as well as an interest by the population for the produced alternative fuel.

7.1 LOCAL BIOMASS FUEL PRODUCTION MARKET CHARACTERISTICS

Around two dozen sellers are observed on the local market offering solid biomass fuel. A significant part of them are, however, importers of briquettes and pellets from Russia. The current prices are in the range of 80-130 thousand AMD (approx. 140-227 Eur), a level that might discourage households to buy fuel from biomass.

The main reason of high prices is the size of currently operating producers in Armenia. There are maybe 5-6 manufacturers whose production capacity is 400-500 kg / hour while all others are in the productivity range of 100-250 kg / hour, managing homemade equipment. There is not much chance to offer competitive products on the market under such circumstances.

The main types of equipment used for briquetting are mechanical, however some hydraulic briquetting equipment (RUF) exists in 1-2 places. A list of producers identified so far has been compiled, as follows:

This registry might contain inconsistencies, nevertheless it represents an attempt to organize the information about the existing initiatives in the field.

The density of briquettes of locally produced varies from 0.8 to 1.4 depending on the production method. The main raw materials for various biofuel briquette products are straw and grass residues (Shirak, Kotayk, Lori), wood processing waste, small residues from horticulture and viticulture (Tavush, Lori, Vayots Dzor, Yerevan) and furniture production remnants (Yerevan).

Although the number of briquette producers in Armenia today is more than two dozen, the quantities produced and marketed by them is relatively small, approximately 1500-2500 tons / year.

Imperfect organization, financing and production processes are among the main reasons of such low overall productivity. Heavy logistics and raw material availability affect the economic feasibility of biomass processing. Also, high prices for raw material combined with the lack of specialized equipment required to pre-process the biomass before transportation and storage makes the goal difficult to pursue. All this, organized in a short season determined by seasonal agricultural works, are elements affecting dramatically the fuel price and its attractiveness compared to other sources of fuel.

Lack of skilled work force and specialists in the field as well as the low awareness of the population are reasons why the solid biomass is still burnt in the field. There is also little support in terms of incentives, therefore the business is run by enthusiasts that believe the idea and are not following the economic reasoning of this activity.

All the above described elements are characteristics of a market at its incipient stages of development, which require support and investment in equipment to collect, store and produce the biomass fuel as well as equipment to use the biomass fuel in an efficient way.

1 https://www.list.am/category?q=%D5%A2%D6%80%D5%AB%D5%AF%D5%A5%D5%BF+%D5%BE%D5%A1%D5%BC%D5%A5%D5%AC%D5%AB%D6%84, https://www.list.am/item/10387031

Table 9 *Producers of biomass fuel in Armenia*

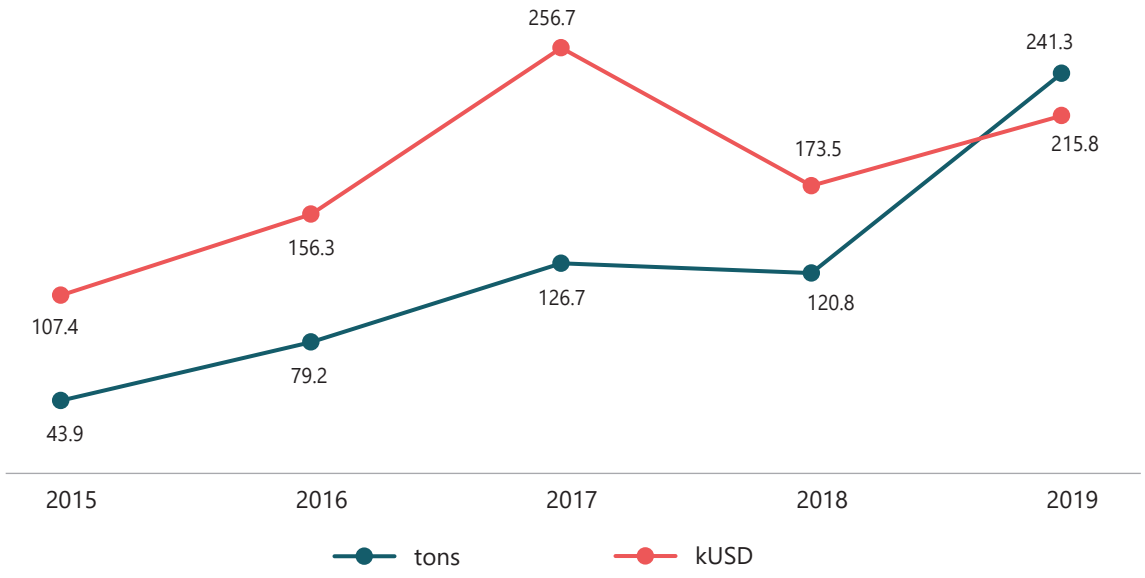
Production place, beginning of activity and product type	Production principle and power line capacity	Ownership and management	The total volume of products produced so far	Contacts
Shirak region of RA, Basen community, 2016 NESTRO Briquettes	Drum Rated capacity up to 200 kg / h Actual production capacity: 100-120 kg / hour	Basen Community Development Fund, UNDP	The main raw material is grass 50-55 tons	Hamlet Petrosyan basenfoundation@gmail.com 095 563600
RA Lori region, Mets Parni community, 2018 NESTRO briquettes	Hydraulic Rated capacity up to 400 kg / h Actual production capacity: 320-350 kg / hour	"METS PARNI" Climate Civil Circulating Investment Fund, UNDP	The main raw material is straw and about 30% wood 550- 600 tons	Gagik Palyan gagik-palyan@mail.ru 55523565
Shirak region of RA, Akhuryan community, 2020. Piny Kay briquettes	Screw drive Rated capacity up to 480 kg / h Actual production capacity: 380-400 kg / hour	Akhuryan Community Development Center Civic Working Fund, UNDP	Production is currently underway and has only undergone a preliminary test	Samvel Safaryan 90404@list.ru Tel: 098 312331
RA Tavush region, Varagavan community, Piny Kay briquettes	Screw drive, Rated capacity up to 300 kg / h Actual production capacity: 300 kg / hour	Armen Abrahamyan Private Entrepreneur	The main raw material is the remnants of vineyards, 180-200 tons of straw wood material	Armen Abrahamyan Tel: 94081000
RA Kotayk region, Zoravan community, NESTRO briquettes	Impact-mechanical, nominal power 500 kg / h	Eco Range LLC,	The main raw material is straw, 900-1100 tons	Suren Davtyan 044 30 07 70 armecorange@gmail.com
RA Lori region, Vanadzor Piny Kay briquettes,	Screw drive, Rated capacity up to 500 kg / h	Eco varm LLC	The main raw material is wood waste About 1000 tons	Karo Dolmajyan 095 883588 karodolmajyan@gmail.com

7.2 LOCAL BIOMASS FUEL CONSUMPTION CHARACTERISTICS

7.2.1 Current market size

The local consumption of the biomass fuel is limited by the produced as well as imported quantities in Armenia. Therefore, with a total of 2.5 thousand tons of fuel per year produced locally and 122 tons average import quantities, Armenia is registering a positive trend. Both local consumption and import is growing, indicating a good interest from the consumers.

Figure 37 *Imports of biomass fuel, Armenia*[1]



Comparing to the level of logwood consumption, the quantities of overall biomass fuel present on the market of Armenia is very small. On one hand, it might indicate a low awareness about the opportunities provided by this type of fuel comparing to others, on the other the lack of knowledge about the business opportunities offered by biomass.

The import figures are also indicating an increase of imported fuel at a decreasing value. This might signal a demand for a cheaper and lower quality fuel, which is obviously more suitable for existing heating solutions used in the rural areas of Armenia today.

7.2.2 Heating solutions currently used in Armenia

The situation with the heating solutions on solid biomass fuel is also at nascent level in Armenia. Most of the households are using handmade, low efficiency stoves for heating and cooking. The main fuel for such stoves is logwood, paper, dung, crop wastes, less briquettes. These technologies are inefficient and the fuel produces high levels of air pollution with a range of health-damaging pollutants, including small soot particles that penetrate deep into the lungs. In

1 https://www.petekamutner.am/Content.aspx?itn=csCIImportStatistics

poorly ventilated dwellings, indoor smoke can be 100 times higher than acceptable levels for fine particles.

The price range for the cheapest solutions used in the country is floating at the level of 40-50 USD. With thin burner walls, these stoves are operational for up to 2-3 years, after which ought to be replaced. Middle price layer of stoves is around 100-200 USD, which makes them a little more reliable but not necessarily more efficient. It seems that the choice of low efficient and low-price heating solutions was the result of a combination of problems mentioned earlier in this report. The first and the most important being the poverty level of population in rural areas, which forces the households to improvise when planning and implementing the heating of their premises. Usually it resembles to using an inefficient steel box where the wood is burnt with no real track of efficiency. Another reason is the technical readiness of the households to embrace high efficiency technologies. More specifically, there is little chance they would install high efficiency biomass boilers on a short run because they are not equipped with necessary internal heat distribution systems. Also, their preferences lay in the area of having a cheap but combined heating and cooking solution with the capacity to burn low and very low-quality fuel (mentioned above) with high efficiency, which is technically not possible due to obvious limitations.

The mandatory pre-conditions households should fulfill when looking for efficiency in heating their premises are the following:

- The heating solution is of certified high efficiency, usually above 80% (only factory made)
- The fuel is of certified high quality (density, moisture, etc.)
- The heating solution is designed to use the selected fuel (technologically proved to achieve high efficiency with the selected fuel)
- The heating solution work is interrupted rarely or at all during the heating season
- The fuel is supplied automatically and does not require opening boiler/stove doors

Of course, these are ideal conditions which can be achieved with biomass heating solutions only if a high level of awareness regarding these technologies is met and households possess the knowledge and skills to manage such systems.

The direct interconnection between the

Picture 23 *Ordinary wood stove used in Armenian villages*

Picture 24 *Round-based stove (spread in recent seasons in Lori and Tavush)*

Picture 25 *"Czech-Georgian" model stove*

performance of both the fuel and stoves determines the main elements of market development principles and successfulness. At policy level, the success of promoting biomass as sustainable fuel depends on the capacity to correctly match the fuel and its burning solution.

Because the status of both the available fuel as well as boilers/stoves in Armenia is at nascent levels, the poor quality of fuel is accompanied by low efficiency of stoves. The poor-quality fuel will not burn well in high efficiency boilers and high density (quality) fuel is not well suited to the stoves with low level of air supply to the burner. Therefore, developing the biofuel market requires simultaneous actions in terms of production and consumption of biomass. In practical terms it means replacing only boilers without fuel quality control, or the vice-versa, may damage the image of biomass as fuel and jeopardize the whole effort of reducing the logwood consumption.

7.2.3 Potential impact of biomass sector development in Armenia

Based on the official statistics there is a consumption of 3,164 TJ of heat energy generated from logwood. The current local production as well as import of biomass fuel, such as briquettes and pellets, is incomparably lower and represents a small fraction of the above.

Following the assumption that only 25% of the total agricultural biomass residues collected in Armenia would be converted to fuel and used to replace the logwood, more than 2,000 TJ[1] in briquettes in pellets would be produced to heat rural households in the country.

This will allow avoid cutting around 144,000 cubic meters of wood per year as well as not less than 114,000 tons of agricultural biomass in the field. The obvious benefits are both environmental and economic. First, avoid cutting the trees means safeguarding the natural ecosystem of Armenian forests and maintaining their area as large as possible. Second, the biomass residues will become a commodity and a resource for producers of biofuel, being in demand and having a price, it will decrease the risks of fires in open field. Environmentally friendly agriculture will bring environment and social benefits, including clean and breathable air in rural areas during the agricultural works, reduce the risks of fires from the fields to the forests, additional income for the agribusinessmen, energy security for households, etc.

The potential economic benefits of biomass market development are huge and can offer perspectives in different areas. Because burning the biomass in the field brings only damage, anything that could make it useful at reasonable prices, is an opportunity. In addition, biomass briquettes as well as pellets may have multiple use. In western countries the briquetting is used as a storing and handling modality for animal fodder. Alternatively, briquettes can also be used as raw material for biogas. Pellets may also be used as fodder and bedding for animals.

To sustainably produce the biomass fuel required to supply the 2,000 TJ there is a need for at least 40 enterprises with an average capacity of 1t/h, to be deployed in Armenia. Based on the availability of resources in each region the average number of production facilities should be distributed in the following way:

Region	# of facilities
Shirak	10
Gegharkunik	5
Lori	4
Aragatsotn	4
Syunik	4
Kotayk	3
Armavir	3
Ararat	2
Tavush	2
Vayots_Dzor	1
Total	40

The investment required to finance this number of businesses will be estimated using the average prices on European market. The turnkey solutions for a briquetting plant ranges between 160-300 thousand Euro, while the same productivity pelleting production facility can reach one million Euro. Under these circumstances the investment required to deploy 40 briquetting facilities can reach up to 12 million Euro in investment, compared to 40 million for pelleting. Nevertheless, a big amount of financial resources is required, the investment should be

1 The average lower heating value of biomass lower heating value used – 17.5 MJ/kg

done considering the development pace of the local market.

Once established, the biomass market will offer industrial products, with well known technical parameters, such as density, moisture, low heating value, etc. At the end of the day, the educated consumer will want to know more about the energy of the fuel, rather than quantity or volume, therefore biomass fuel will definitely surpass the logwood as a commodity. Under these circumstances there will be no need to protect the trees from cutting and the ecosystems will be preserved by all people of Armenia.

AWARENESS LEVEL OF **BIOMASS POTENTIAL** IN ARMENIA

8 AWARENESS LEVEL OF BIOMASS POTENTIAL IN ARMENIA

Biomass as fuel is a subject which has never been left aside without attention. Because of the energy crisis in middle of the 20th century, biomass has become increasingly interesting and demanded on the EU market. The experience of countries like Denmark, Sweden, Finland shows a wide range of biomass uses, including big power plants 100% run on biomass fuel. Though, there are voices claiming biomass is dangerous and does not really contribute to environment protection, the debate is still in frontlines. The level of awareness regarding the biomass as a renewable source of energy is the driver that keeps the work on and makes its use more sustainable. Because it is not a panacea to all energy needs a country may have, biomass use may be more or less attractive and therefore similarly sustainable to different countries.

Knowledge and skills are the backbones of the success in increasing the awareness level about biomass fuel. For instance, the ability of a consumer to determine the quality of the fuel or to operate a biomass boiler, increases the chances it is used by the target beneficiaries.

The ability to inform the beneficiaries about the alternative source of energy requires a great level of professionalism, experience and adaptability to the clients' needs.

Armenia has paid little attention to biomass as an energy resource until now, but still the general population is aware of the main characteristics' biomass has, such as:

(1) The biomass is renewable and abundant. It grows each year as long as crops are cultivated

(2) The biomass is available. It usually surrounds households in rural areas; therefore, they are cost effective

(3) Biomass is a labour-intensive technology and requires storage space

(4) Biomass is not competitive with fossil fuels

(5) Biomass residues cannot generate heat

Some of these beliefs are certainly true, but only in specific circumstances. It is not necessary that biomass is abundant, but carefully and economically gathered and processed. The households may be surrounded by biomass but may not be able to use it in feasible way.

The overall awareness, except specialists in the field, is middle to low. This is due to severe lack of technical details and confusions about the nature, technologies used, etc when implementing projects related to biomass. Another factor determining the overall scepticism about this subject is the current habits and traditions in using it. Unforgettable smell and labour-intensive technologies are usually the first thoughts of people questioned about the use of biomass. This happens because biomass is associated with dung, which remains to be the only real knowledge about this subject.

Therefore, the awareness about modern use of biomass should be started from scratch in Armenia. Though it might seem an additional effort, the beneficiaries will be able to get informed from credible sources of information, cancelling all myths and old beliefs they may have about using biomass for fuel.

TOWARDS A SUSTAINABLE DEVELOPMENT OF BIOMASS USE FORHEATING IN ARMENIA

ROAD MAP

TABLE OF CONTENT

1 INTRODUCTION

Biomass sector development is needed for Armenia for several reasons. As mentioned earlier, the sector could solve two major issues the country has no solution:

1. Uncontrolled and illegal wood cutting
2. Burning of biomass residues in open field

Both have irreversible impact on the environment and represent a considerable threat to the environment and the health of its citizens.

This document is a logical continuation of the attempt to systematize in an analytical report all available information regarding the biomass potential, current level of consumption, potential for production of biomass fuel, potential technical as well as legal improvements required for the sector to kick off. It will provide practical recommendations via a step by step approach towards biomass supply chain and use for energy purposes.

2 CONTEXT AND APPROACH

Based on the conclusions of the analytical report, it is obvious that only a small share of vegetal biomass residues is used in Armenia for energy purposes. Most of it is still burnt in open field. On the other hand, the fuel poverty in the rural part of the country is a major subject of concern, which for the moment does not have a straightforward solution. In this context, but also based on the problems with illegal wood cuttings, the biomass sector development has the great potential to be the key to solving these problems.

Because of a low level of biomass projects implementation in Armenia, it is difficult to provide exact details about the structure, preferences, potential use of biomass that is currently used for energy purposes. The figures provided in the analytical report are approximate and may be adjusted at later stages when their exact values are important for the statistical and baseline purposes.

Until then, the first steps that should be taken to kick off the market development are targeting the primary demand and supply. These are the core elements that should be carefully analyzed and responded properly. The existing biomass processing businesses in Armenia is a proof that businesses always respond to a demand from their customers. The existence of both elements demonstrates the incipient level of biomass market development which should be supported to grow faster.

Creating the demand for biomass should be done considering its value chain, which is composed of the following:

In practical terms, the starting point of this market is the type of the raw material we consider for its development. Based on this, other decisions along the value chain are taken. For instance, the equipment designed to make briquettes and pellets from wood residues is not fit for straw. Similarly, the boilers designed to burn wooden briquettes and pellets experience serious problems if fed with agricultural residues fuel.

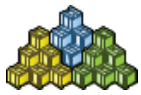
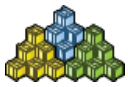
As soon as the major quantities of vegetal agricultural residues Armenia possesses resembles to cereal straw, the focus of further plans and actions should be put exactly on this type of raw material. As a result, to achieve a balanced and flawless approach towards biomass promotion as fuel it is necessary to make straw the key element of the biomass market support programs.

To achieve tangible results in its short, mid and long-term plans, the GoA should develop a National Biomass Sector Development Program, which will provide the necessary status and institutional support to activities aiming at developing the sector. Action plans which will provide operational details about the program implementation shall be developed and approved for each region separately.

The following areas should be part of the national policy documents of Armenia in this sector:

1. Regulatory framework
2. Incentives and subsidies
3. Biomass heating solutions
4. Biomass fuel production
5. Quality standards and the sustainability of the biomass fuel
6. Promotion, awareness and stakeholders training

This roadmap will provide recommendations in support of developing the necessary documentation as well as practical steps required to boost the interest in using biomass as fuel in Armenia.

	Ենթամթերք արտադրողի արժեշղթան	Արժեշղթա
1	• The biomass is obtained as a residual from the main activity; • The biomass is collected and transported to storage;	 Biomass from agri residues
2	• The storage conditions for biomass can resemble to sheds; • There should be fire security conditions within the storage facilities; • The biomass is transported to the production facility;	 Storage of biomass
3	• Fuel production is done on equipment suitable to the raw material; • The equipment is organized in a consecutive logic chain comprising operations such as drying, grinding and pressing; • The fuel is packed according to the specific customer preferences;	 Production and packaging
4	• Storage of fuel is done in line with technical requirements in a dry, sheltered and secure space, equipped with fire protection equipment;	 Storage of pellets
5	• Transportation is done with units designed to transport the fuel in the client preferred package (sacs, bulk, etc.);	 Transportation
6	• Sales are organized via different channels; • Consumption of biomass fuel is done in suitable boilers, designed to burn the specific biomass provided by local producers;	 Sales and Consumption

3 REGULATORY FRAMEWORK

The regulatory framework proposed to develop the sector should mainly focus on market stimulation, rather than restrictions. Burning the agricultural waste in the field should mandatory be accompanied by incentives to trade them to producers of fuel. Therefore, the main focus should be to create opportunities for the potential suppliers to get an additional profit from trading the residues.

On short term it is recommended to conduct an impact assessment for the proposed tax relieves along the value chain, including supply, production, trading, consumption. The assessment will quantify the impact on the budget and the possibility of their implementation in short, medium or long perspective. Also, this exercise will clarify what is the fiscal burden on each of the value chain elements. It should provide clues for additional legislative changes required to improve the performance of the sector.

The main questions the RIA should answer are:

- What are the main types of taxes and duties that affect biomass fuel producers currently and what is the absolute value of the taxes collected by the budget?
- What is the share of the main taxes and duties in the delivery value of biomass fuel and their wight in the total taxes collected

from the respective businesses?

- Are there any tax incentives that can currently be beneficial to biomass fuel producers?
- What is the influence of VAT on the process of production and delivery of biomass fuel?
- What fiscal measures, including the application of VAT, are necessary to effectively stimulate the development of the biomass fuel production sector?

Changes to the fiscal legislation should be developed based on the findings of the above-mentioned assessment and publicly debated with all stakeholders. It is important to get as much as possible participation in the debates held in the regions where the businesses are expected to appear. Considering the low number of briquettes and pellets productions currently established in Armenia, it is expected that the national budget will hardly loose too much in taxes, nevertheless the detailed assessment will provide exact figures.

Adopting and enforcing the changes to fiscal code should be presented and communicated to stakeholders and potential businesses that are operational or intend to kick off. It is recommendable to establish a special fiscal space for producers of biomass fuel for a period of 5-7 years, providing tax deductions and exemptions. Offsetting these fiscal privileges should be done gradually once the sector is will established and will start working properly.

Subsidy programs could be developed to support supply chain, production as well as consumption of biofuel and by this target all value chain participants. Direct subsidy programs aiming to develop the sector should be considered on short-term perspective, while the tax deductions or tax credits should be implemented at later stages of market development. It is worthwhile mentioning that direct subsidies should be applied to businesses on exceptional basis, otherwise the risk of spoiling the market is very high.

4 BIOMASS SUPPPLY AND FUEL PRODUCTION

4.1 BIOMASS ASSISTANCE CROP PRODUCTION AND HANDLING PROGRAM

It is one of the recommended tools to support the raw material suppliers. This type of programs envisages ***direct subsidy for supply of quality biomass to a production facility***. There is a wide group of qualified suppliers which can take part in this, but preliminary registration is required. On a short run the program can be piloted in regions like Shirak, Tavush and Lori, regions with highest potential of agricultural residues and scaled up in all other regions once the positive results are achieved. The subsidy shall compensate ideally ½ of the total cost of residues collection and supply to a specialized fuel production facility. The focus should be put on quality along the supply chain of biomass. This tool can be combined with other subsidies in the agricultural sector, serving as a precondition for funds disbursements *(e.g. existing cereal corps subsidies are released only if a contract for processing the residues is presented within the application package)*. For the tool to be operational, it should be enforced by a strong monitoring and verification component. Additionally, a close communication with producers should be maintained to support the correct distribution of subsidies.

4.1.1 Agricultural raw material supply

Period of implementation: 3-4 years (potentially 2021 – 2025)

Objective:

- Create the market for raw material steady supply;
- Decrease the quantities of agricultural residues burnt in the field;
- Reduce the negative environment effects as well as the risks associated with open field and forest fires;

Expected benefits:

- Not less than 50 producers of biomass suppliers supported to deliver quality biomass to processing units;
- Suppliers are equipped with machines and

tools necessary to collect transport and store the raw material;

- The level of demand for locally produced biomass fuel (from agricultural residues) has increased;
- The level of illegal wood cutting has decreased;

Program logic: a supplier of biomass is eligible to get a subsidy for the supply of agricultural residues to a processing unit. The supply should be confirmed by contract and invoices. The program can be combined with other existing subsidy schemes in agriculture, like the one related to quality cereal seedling material, currently operational in Armenia;

Budget: Approx. 500,000 Eur with possible extension.

Recommended financing modality:

Direct subsidy or tax deduction at the end of fiscal year.

Main selection criteria:

- Current producers of cereal crops willing to increase the added value of their crops;
- Availability of specialized equipment or a rental contract for equipment to collect and transport agricultural residues

4.1.2 Energy forest program

It should be another direction in terms of increasing the volume of raw material traded on the local market. It is a mid-term activity which should be financed starting the first moments of market development. Initially, it should be focused on R&D elements with piloting of small plots of different types of energy crops. On a mid-term perspective, the scale-up should be done via specialized programs dedicated to support alternative sources of raw material for biomass fuel production.

Period of implementation: 7-10 years (potentially 2021 – 2031)

Objective:

- Increase the volumes and quality of locally produced raw material for fuel production;
- Create additional added value from marginal and depleted lands;
- Reduce the illegal wood cutting by offering sustainable alternative raw material for biomass fuel production;

Expected benefits:

- At least 100 energy forests of 10 ha each created and yielding at least 30 tons of dry matter per hectare;
- 30,000 tons of additional biomass raw material and quality biomass fuel is supplied to the market;
- 100 communities manage their energy forests and receive income from trading raw material for biomass fuel production

Average cost per project: 20 – 30,000 Euro for a plantation of 10 ha, including seedlings and works

Budget: Approx. 2,000,000 – 3,000,000 Euro

Recommended financing modality:

Matching grant with minimum 50% beneficiary's contribution. A combination of soft loan and grant could also be an option but depends on the financing terms of Local Public Authorities in Armenia.

Main selection criteria:

- Average poverty level of the community;
- Access to wood resources and the share of wood in the final energy consumption of the region;
- Lack of raw material for biomass fuel production and high interest of the beneficiary to cultivate energy crops, which is stated in an expression of interest/ application;
- The applicant is a community which has the intention or is already using biomass as fuel in one of its institutions;
- The local authority has the potential to manage energy forests and can assign a specialized person to take responsibility for it.

4.1.3 Lease-purchase of equipment for harvesting and transporting the agricultural residues

Period of implementation: 10-15 years (potentially 2021 – 2036)

Objective:

- Strengthen the overall supply chain of biomass residues;

- Increase the number of biomass raw material suppliers to fuel production facilities;
- Increase the quality and price of the residues supplied to production facilities;

Expected benefits:

- Not less than 500 biomass suppliers supported to deliver quality biomass to production facilities;
- Suppliers are equipped with machines and tools necessary to collect transport and store the raw material;
- The overall quality of supplied biomass residues has increased;
- The price level of supplied biomass residues has decreased;

Program logic: potential suppliers of biomass are eligible to procure baling, cutting, shredding, transportation and other relevant equipment to optimize the supply chain operations and provide more raw material to biomass fuel production facilities. The program allows agricultural producers to procure equipment and collateralize it to guarantee the cost reimbursement. The program can be combined with other existing subsidy schemes in agriculture, which are stimulating the use of modern equipment in agriculture;

Average cost per supplier: 40.000 Eur

Budget: Approx. 20,000,000 Eur

Recommended financing modality:

Low interest lease hire purchase of equipment used on a revolving principle

Main selection criteria:

- Current producers of cereal crops willing to increase the added value of their crops;
- Availability of specialized equipment or a rental contract for equipment to collect and transport agricultural residues

4.1.4 Medium- and long-term perspectives

The above mentioned are high priority actions that should be taken to kick off the activities in the sector immediately. Supportive measures, with lower priority and longer time perspective, could be done to consolidate these efforts. They can be as follows:

Developing a register of trustful suppliers of biomass - a measure required to protect the producer of biomass fuel. It is of a paramount importance that the producer trusts the quality of the supplied raw material. Keeping the register updated on a permanent basis represents the main challenge which should be done on a dedicated platform.

Community initiatives – could be beneficial to introduce the experience of communal management of assets for the benefit of its members. A similar model is being developed by UNDP in Armenia, which could be used to pilot biomass supply chain elements. Based on the experience of local communal enterprises managed by local authorities, communities can collect and supply raw material to biomass fuel production facilities and get additional profits which can be monetized or collected in the form of fuel. The same is the energy forest scale up activity, which has the potential to become a consistent income budget line of Armenian villages.

Supporting the raw material suppliers should be planned as a continuous measure. It should support the renovation of supply chain equipment and infrastructure, raw material quality improvement as well as trading efforts. As a high priority, all of the activities mentioned above are aiming at educating a market benefiting of quality raw material supply, while in time perspective it should move towards commercial based sustainability and less grant support.

4.2 BIOMASS FUEL PRODUCTION SUPPORT PROGRAM

It should be conceived to increase the level of processed agricultural residue in the country. The most successful and attractive tools to potential businesses are leasing programs. The aim of such programs is to support the development of a private sector market for contractors wishing to be fuel suppliers. Straw handling equipment such as balers, trailers, bale handling tractors, briquetting and pelletizing equipment should be provided using lease-finance models.

An institutional partner, (e.g. R2E2) could play the PIU role to manage a revolving fund designed to provide financial assistance to local producers willing to initiate or extend the biomass processing business. The aim is to provide potential beneficiaries with access to

structured financing for the agricultural sector. This would finance the needed development of the fuel cycle without the need to provide grants to private sector fuel-supplying enterprises.

4.2.1 Hire purchase of production equipment

Period of implementation: 5-7 years (potentially 2021 – 2025)

Objective:

- Increase the number of biomass fuel suppliers on the local market;
- Decrease the prices for locally produced biomass fuel due to tighter competition
- Increase the quality of the biomass fuel supplied to the local market;

Expected benefits:

- Not less than 40 producers of biomass fuel supported to deliver fuel to the market;
- Producers are operating equipment matching the characteristics of the raw material used;
- The overall quantity of biomass fuel has increased on the local market;
- The price level of supplied biomass fuel has decreased;

Program logic: potential producers of biomass are eligible to procure briquetting and pelleting sets of equipment to produce biomass fuel. The program allows local entrepreneurs to procure equipment and collateralize it to guarantee its cost reimbursement.

Average cost per supplier: 160.000 Eur

Budget: Approx. 7,000,000 Eur

Recommended financing modality:

Low interest lease hire purchase of equipment used on a revolving principle

Main selection criteria:

- The applicant possesses a suitable facility to start/expand the production. The facility should have water and electricity supply. Also, it should avail space and sheds for the raw material storage;
- The applicant has a steady inflow of raw material for at least 6 months of operation;
- The applicant is trained and knows how to operate a biomass fuel production line;

4.3 MEDIUM- AND LONG-TERM PERSPECTIVES

Apart from financial support there are a number of activities that are mandatory for the balanced market development. Exchanges of experience with producers form countries with longer traditions in this field, on-the-job trainings conducted by practitioners would eventually lead to the need of educating and certifying local specialists. Supporting professional association initiatives would also provide a steady flow of information about the local market trends and developments. This will lead to the need of stimulating the trade and identification of customers. All parameters of medium to long term support programs should be defined on the way, providing implementation scenarios based on the current development stage of the market.

5 BIOMASS-BASED HEATING SOLUTIONS

Biomass requires the development of many different elements in its supply chain. It is vitally important to develop a number of good quality pilot / demonstration projects. Not only do they enable many valuable lessons to be learnt which can be disseminated throughout the industry, but more importantly they provide tangible examples to people considering entering the industry that such technologies are viable and not unduly 'risky'.

Municipal pilot projects would have the potential to solve the heating problems in schools and kindergartens of the country. A good start would be to pilot new biomass systems in the buildings where these are non-existent or are expensive. According to official statistics[1], 9 education institutions in the country have no heating systems, which gives a high demonstrational potential to new biomass boilers that could be installed.

1 The social situation of the Republic of Armenia in 2018. Activities of general education institutions

Region	# of institutions with no heating system
Aragatsotn	2
Ararat	2
Armavir	2
Lori	1
Shirak	2

On a short perspective, it is recommended to start piloting heating system on biomass in the above-mentioned institutions and gradually promote them in others where the heating costs are higher than average. For instance, **439** out of a total of **1409** schools in the country using electricity or inefficient stoves, which makes them prefect promoters of biomass. Due to higher costs comparing to other sources of energy, there is high probability of achieving considerable savings in terms of energy costs as well as increase the level of internal comfort in those buildings. There will also be less resistance to new solutions, which will make the implementation smoother.

5.1 BIOMASS-BASED HEATING IN PUBLIC INSTITUTIONS

A program providing financial and technical support to the ***public institutions*** with poor heating systems aiming to switch to biomass as primary heating source could have the following parameters:

Period of implementation: 3-4 years (potentially 2021 – 2025)

Objective:

- Improve heating comfort levels in public buildings in target rural communities by using available waste straw supplied from local agricultural enterprises;
- Increase the demand for locally produced biomass fuel

Expected benefits:

- At least 30 biomass heating systems installed in educational buildings of the country
- Local public authorities, civil servants, teachers, straw-fired boiler operators, fuel suppliers, and school children have knowledge, capacities and motivation, leading to growth of biomass markets at regional and local levels.

Average cost per project: 90,000 – 120,000 Euro for a biomass boiler of 300kW[1] (approx. 3000 m^2 area of the building) and the internal heating system (pumps, valves, fittings, pipes and radiators)

Budget: Approx. 2,700,000 – 3,000,000 Eur (only equipment)

Recommended parameters of biomass boilers

Recommended financing modality:

Matching grant with minimum 10% beneficiary's contribution. A combination of soft loan and grant could also be an option but depends on the financing terms of Local Public Authorities in Armenia.

Characteristics	Boiler type		
Fuel type	**Pellets**	**Briquettes**	**Mixed**
Diameter (mm)	≤10	≤100	≤100/≤10
Length (mm)	≤30	≤500	≤500/≤30
Power (kW)	200-500	200-500	200-500
Efficiency (%)	>80	>80	>80
Autonomous operation (number of working hours without operator intervention)	at least 6	at least 6	at least 6
Electrical connection (V)	230 - 380	230 - 380	230 - 380
Automated control panel	mandatory	mandatory	mandatory

1 The average size of a school in Armenia is around 2800 m2, therefore the indicative value for installed power of boilers is 300kW.

Main selection criteria:

- Poor or no heating system available and ***high willingness*** of the beneficiary to switch to biomass as primary energy source.
- Availability of co-financing and willingness to learn about the new technologies
- Capacity to assign a person to be responsible for the boiler and its operation

A second phase of the program could be launched after the successful implementation of the pilots. A pool of ***448 education institutions*** could be modernized with biomass heating systems, providing a good and sustainable example of using local agricultural residues as fuel. The size and conditions of the project extension will depend on the achievements and lessons learnt of the pilot phase. Further support of offered to biomass should be similar to other alternative sources of energy supported by GoA.

The effects of modernizing the above-mentioned institutions would bring economic, environment, health, comfort benefits to all pupils and staff on a long-term perspective. The fine particles emanated by the stoves would likely reduce the morbidity of pupils and staff, the use of a high efficiency boiler would reduce.

The economic effects of switching to biomass in all 448 education institutions have the potential to produce around **612,864 MWh**, increase the demand for biomass fuel by around **59,000 tons** per year which accounts for approximately **7.1 mil Euro**[1] in current prices of biomass fuel sold on the local market. More than 100,000 tons[2] of CO2 per year emissions could be reduced when schools are converted to heat by biomass.

5.2 HOUSEHOLD HEATING SOLUTIONS

A program to support the promotion of household heating solutions could be piloted to respond to the need of stopping illegal wood cuttings. It is recommended to start piloting the program in the whole country, but with a special focus in the regions like Ararat, Armavir, Gegharkunik, Lori and Tavush. The level of wood consumption in these regions is the highest, with 65%[3] of the households using wood for heating. Because of the good potential of solar energy in Armenia, a good opportunity to successfully promote the program is to combine biomass boilers with solar collectors, which would produce hot water in the taps.

Period of implementation: 3-4 years (potentially 2021 – 2025)

Objective:

- Create the national market for efficient household heating with a combination biomass boilers and solar water heaters;
- Increase the demand for biomass heating solutions and therefore support local biomass heating solutions producers and importers to offer higher efficiency solutions;
- Increase the demand for locally produced biomass fuel;

Expected benefits:

- Not less than 500 combined[4] biomass heating systems installed in households of Armenia;
- Households are aware and have skills, capacities and motivation, leading to the use of modern biomass-based heating solutions;
- The level of demand for locally produced biomass fuel (from agricultural residues) has increased with at least 16,000 tons of biomass fuel;
- The illegal cuttings are gradually reduced and a lower comparing to the same period of the previous year;

Average cost per project: 2,000 Euro grant for a heating system average cost of 3,000 Euro (boiler, pumps, valves, fittings, pipes and radiators).

Budget: Approx. 1 000 000 Eur (in equipment) with leverage from beneficiaries' contributions of 500,000 Eur

Recommended financing modality:

Matching grant with minimum 60-70% beneficiary's contribution combined with soft

1 The average price of fuel used for calculation is 120 Euro/ton

2 Source: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf

3 Firewood consumption market study, Armenia (2007-2018),

4 Biomass combined with water solar collectors for the preparation of hot water.

loans (subject of further discussion with local banks). The parameters of the program can be gradually hardened once the demand for the program increases.

Main selection criteria:

- Willingness to install combined biomass-solar heating systems
- Availability of an offer from an official distributor of equipment (offer should include the costs for turn-key solution)
- Proof of contribution availability (bank excerpts or loan agreement with a bank)

Recommended technical parameters of the household biomass boilers:

The reference values for the biomass boilers performance should be clear and sufficient to include a wide variety of producers which can propose the heating solutions to the consumers on the market.

This list of technical parameters of the boilers is indicative and can be adjusted to increase the efficiency of eligible solutions. This, however, should be done at later stages when preferences of households will shift towards more sophisticated and autonomous models of boilers.

Direct or indirect subsidy for the procurement of biomass fuel could be applied on short and mid-term perspective. Direct payments or tax deductions could be used to incentivize households to use as much biomass fuel as possible. Specifically, a program of this type can target replacement of wood with biomass fuel, which is expected to have a positive impact on the reduction of illegal cuttings. A program could be implemented at later development stages of the market and requires administrative effort for supervision and verification.

Incentives to local producers, assemblers, importers of biomass heating solutions could be offered in a number of ways**. Import duties to direct production equipment**, spare parts for boilers and assembled boilers could be temporary cancelled to allow a decrease of prices of heating solutions sold on the market[1]. This measure should be temporary and may alternate with other support measures required by the market stakeholders.

Special support measures like **transport cost compensations**, can be offered to importers and producers of biomass heating solutions. Due to geographical position of Armenia, the cost of transport may contribute significantly to the final price of the heating solution, therefore partial compensation of the cost could be used as a measure to support the economic attractiveness of biomass boilers. A share of 25-30% of the transportation cost could be covered for sold boilers, but under the framework of a dedicated and strictly monitored program. Such programs could be financed and implemented by donors or development partners.

Table 1 *Recommended characteristics of biomass boilers*

Characteristics	**Boiler type**		
Fuel type	**Pellets**	**Briquettes**	**Mixed**
Diameter (mm)	≤10	≤100	≤100/≤10
Length (mm)	≤30	≤500	≤500/≤30
Power (kW)	12-25	12-25	12-25
Efficiency (%)	>75	>75	>75
Autonomous operation (number of working hours without operator intervention)	at least 6	at least 6	at least 6
Electrical connection (V)	230	230	230
Automated control panel	optional	optional	optional

1 Due to country membership in the Eurasian Economic Union, the opportunity of reducing import duties to products coming from outside the union should be additional checked.

5.3 MEDIUM- AND LONG-TERM PERSPECTIVES

The need of demonstrating the biomass fuel sustainability depends on all elements of the value chain, nevertheless the most visible part is related to the relationship between the end consumer and biomass-based boiler. It is rarely successful from the beginning because the final user has a low level of awareness and qualification to use biomass as fuel. The natural human resistance to changes and to new technologies, perceived many times as sophisticated, are not favoring any improvement if left alone. Piloting well thought and implemented biomass heating solutions in public sector as well as private households proved to be the best way of convincing stakeholders about the way the sustainability can be achieved. Evaluation and selection criteria are among the most important initial steps that should be carefully developed and applied. The buildings having the best potential to prove biomass fuel sustainability are socially important, like schools and kindergartens, with no or poor access to heat, with high attendance and with almost no other alternative to improve the level of internal comfort in the building. Programs to financially support the implementation of biomass boilers in public and private (residential) sector should be accompanied by strong capacity building activities. They should aim at formalizing the boiler operator specialty and introduction of qualified service provision as well as shifting the support towards commercial market conditions.

Tax relief is a **long-term measure** to support the equipment importers, assemblers and producers of biomass heating solutions. Periodic tax relieves could be beneficial for the financial strength of companies in the sector. There is a prominent seasonality trend in this business, with many contracts during fall and almost no activity during the rest of the year.

Soft loans combined with grants could be offered to local assemblers for production needs. It could target mid and **long-term** financing of equipment, production tools, working capital, etc. The measure can be applied when the demand for boilers is sufficient for the producer to plan for debt commitments. A share of 15-20% could be offered to local entrepreneurs dealing with production/ assembly / import of biomass boilers. This has a good potential to increase the range of offered technical solutions on the market as well as retain a part of the added value locally.

Also, on **mid- and long-term perspective**, the program could be modified to gradually shift it to commercial financing conditions. It will, nevertheless, depend very much on the initial feedback of the households to proposed financing and the appetite of local banks to partially finance the program.

6 BIOMASS QUALITY SUPPORT PROGRAM

6.1 SHORT TERM AND HIGH PRIORITY MEASURES

A program to ensure the quality of the supplied biomass fuel on the market of Armenia, should be considered as one of the first and most important steps taken. It would eventually determine the successfulness of the overall effort to promote biomass as sustainable fuel locally. Steps to clarify the need of addressing the quality topic should be started with a careful analysis of existing standards applicable to biomass fuel as well as identification of the most qualified institution to deal with this topic. Developing national standards for biomass fuel applicable to the existent raw material in the country should be the next initiative taken to create a healthy environment of the market. The most investment intensive activity relates to establishing a quality laboratory for biomass fuel. It, however, is relevant only when the standards are in place and activities to enforce their implementation are started.

The estimated parameters of establishing a quality certification laboratory are as follows:

Period of implementation: 2-3 years (potentially 2026 – 2029)

Objective:

- Elaborate national standards for biomass fuel in Armenia
- Develop the play rules for the producers willing to produce quality fuel
- Establish an authority with the mandate to

provide quality certificates

- Protect the consumer of biomass fuel from using low quality fuel
- Protect the market from unfair competition

Expected benefits:

- Quality standards developed and approved locally;
- Quality certification laboratory established and equipped;
- Use of low-quality biomass decreasing;

Budget: Approx. 250,000 Eur (in equipment), if established as separate institution

Recommended financing modality:

- Grant

Main selection criteria:

- Level of competence
- Available staff
- Existing equipment

Recommended technical parameters of the quality testing laboratory equipment:

This list of technical equipment and parameters is indicative and could be supplemented with additional units. The important element is to cover both the mechanical parameters of the fuel as well as its chemical composition.

Table 2 *Measurement equipment and its parameters*

Parameter	Measurement Equipment
Moisture content	Thermogravimetric analyzer, drying oven with temperature range of 105 ± 2 ◦C, Digital weighing scale
Density	Digital weighing scale, digital or manual caliper
Water resistance	Digital weighing scale, digital or manual caliper
Shatter index	Digital weighing scale, meter rule, steel plate, sieve
Compressive strength	Universal Testing Machine
Durability	Durability tester
Calorific value	Bomb calorimeter
Ash content	Furnace with a temperature range of 550 ± 10 ◦C
Volatile matter	Furnace with a temperature range of 900 ± 10 ◦C
Carbon (C)	Element analyzer
Hydrogen(H)	
Nitrogen (N)	
Sulphur (S)	Atomic emission spectrometer

6.2 MEDIUM- AND LONG-TERM PERSPECTIVES

Quality is a cross-cutting issue when it comes to biomass fuel production and consumption. Its correct implementation and constant support and monitoring is among the most important functions required for the market to function well. Adopting standards and investing in equipment is, nevertheless, far not sufficient for this. All activities concerning equipment and biomass fuel should gravitate around quality insurance.

Enforcing the implementation of quality standards for public sector represents a priority, which is applicable only after the legal and institutional frameworks are in place and functioning.

Primary test quality tests can be also conducted by consumers themselves. Before getting to testing the fuel in a specialized laboratory the regular consumers could be enabled to make distinct difference between low- and high-quality fuel. It can be achieved through capacity building activities enabling consumers to identify on the spot primary quality of the fuel.

Long term measures of increasing the standards at each stage of the value chain are activities having low priority now and should be regarded as such.

7 PROMOTION, SKILLS AND HUMAN RESOURCES

7.1 SHORT TERM ACTIVITIES

Actions aiming at raising the interest for the biomass as fuel should be done as first steps towards the overall objective of increasing the awareness about the subject. It is important to have a clear strategy before initiating any actions, otherwise a wrong message could jeopardize all further efforts. Therefore, a carefully planned and duly organized media campaign is the key to an expected immediate and positive result. It should use all channels to reach the final consumer, including TV, radio, internet, paper-based press, as well as direct communication during public events.

It is well known that during initial stages of market development there are many negative stereotypes and inertia of consumers about the biomass as fuel. The campaign should target credibility of the messages, by organizing interviews with opinion creators as well as presentations of successfully implemented projects in the country. These are going to help improving the overall opinion consumers have about briquettes and pellets.

Dedicated TV shows can provide additional arguments to uncertain consumers for a better decision making. Also, it will provide information to those consumers who are willing to increase the level of knowledge in the sector. **News and TVs shows should be considered as immediate effect tools which would increase the level of interest for biomass**.

Involving the young generation in the subject proved to be highly effective. Organizing recreational events in combination with equipment shows at local level had an exponential effect. Being more sympathetic to new technologies, youngsters enticed their parents and relatives in the matter. (e.g. Open air shows with concerts fed by solar energy could have a good impact on the interest for new technologies). All events should be informative and provide printed take-away information, that would help future beneficiaries learn about the new opportunities.

7.2 MEDIUM- AND LONG-TERM ACTIVITIES

On medium term, formalized information provision should be organized for all stakeholders. Classes to teach young generation about alternative sources of energy should be conducted to present the benefits of using it. Training for trainers should be organized to scale up the learning effort at local level. A wide variety of possibilities exist when it comes to training process. In special cases, students can get access to direct experience classes with equipment in operation, which proves to have the best impact on their further skills. These can be organized in schools, colleges and universities or during dedicated summer camps where participants are selected on open competition basis.

Trade support should be one of the key elements of the medium terms market strategy. Virtual platforms are the ideal places where both the producer and the consumer can meet at a hand length distance. The implementation of a dedicated platform is required only if there is no trading portal exhibiting products of this type. Otherwise, it makes great sense to consolidate existing resources by financing additional effort related to promoting biomass as a fuel.

On long term, events praising the efforts and positive results of the pioneers in promoting biomass as fuel should be organized once in 2-3 years. At later stages of market development, based on the number of new projects, it might have sense to organize them more often.

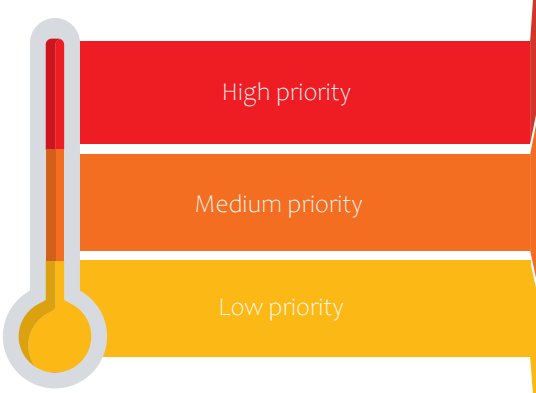
Training skilled workers along the value chain is important and is the ground for the sustainable development of the sector. Though the basis of training specialists in the field would be organized at early stages of development, the expected long-lasting effect will be achieved later with sector consolidation.

Biomass Sector Development

ARMENIA

2021-2040

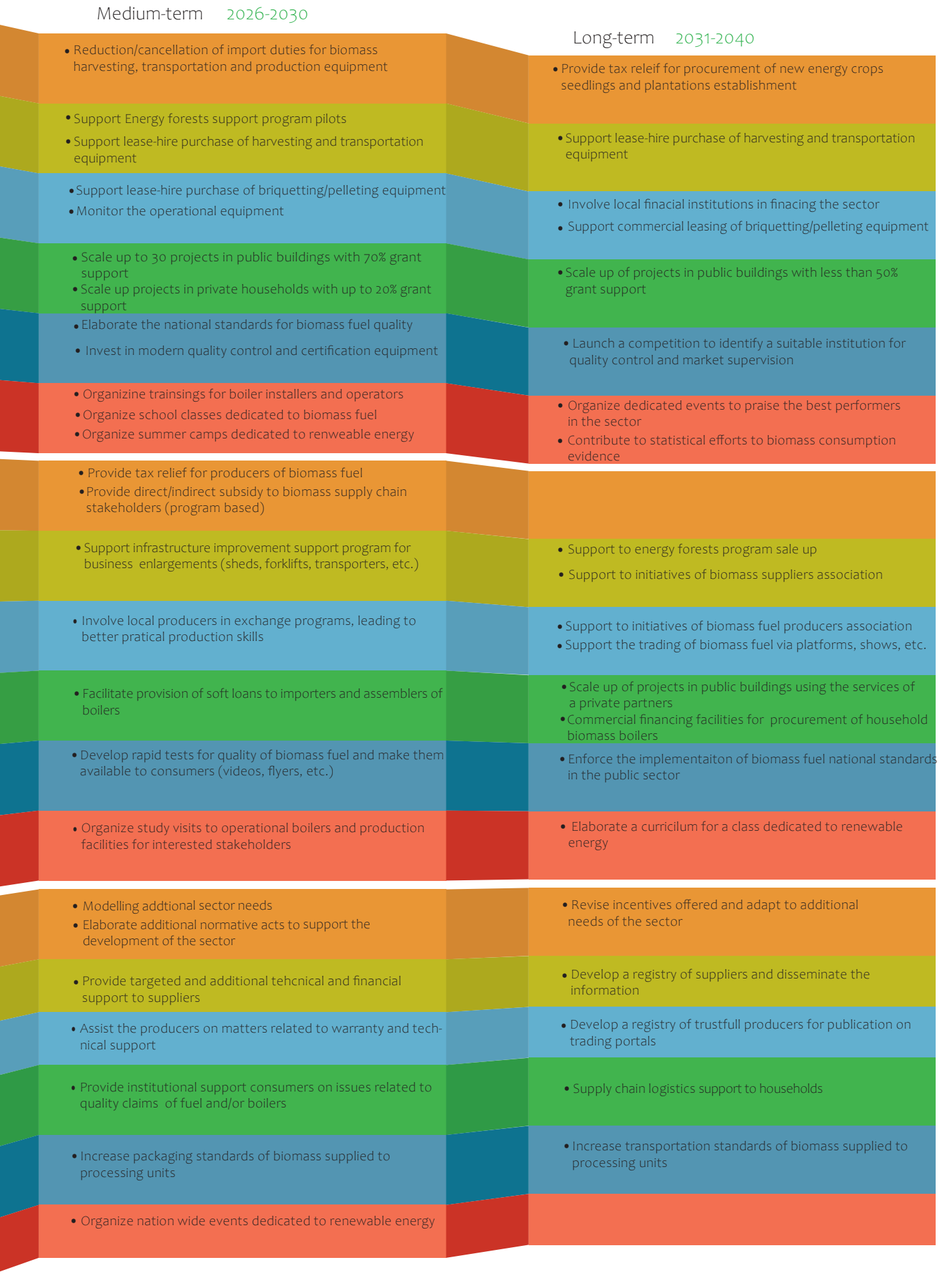
Roadmap



- Regulatory framework & Incentives
- Biomass supply chain
- Biomass fuel production
- Biomass-based heating solutions
- Biomass quality support program
- Promotion, skills & human resources

Short-term 2021-2025

- Regulatory Impact Assessment (RIA)
- Incentivise households to sort their waste
- Restrict the legislation regarding the incineration of vegetal residues in the fields
- Start an agricultural residues supply support program via direct incentives
- Initiate energy forests support program (R&D)
- Support lease-hire purchase of briquetting/pelleting equipment
- Facilitate on-the-job trainings for producers of biomass fuel
- Pilot 9 `projects in public buildings with 95% grant support
- Pilot projects in private households with up to 50% grant support
- Identify the biomass fuel standards set, applciable to the conditions of Armenia
- Identifiy institutions capable to manage the quality issues of bimoass fuel
- Organize awareness campaigns to promote the use of biomass fuel at all levels
- Thematic eudcation and recreational events held for different categories of stakeholders
- Provide soft loans with grants to producers and consumers of biomass fuel
- Introduce the notions of biomass into all relevant legislation (EE law, waste management legislation, etc.)
- Support program to register as many local producers as supply chain agents
- Support local community based initiatives to cooperate on subjects of biomass supply chain
- Formalize the biomass fuel production speciality
- Initiate certification process of boiler operator specialists (similar to other boilers)
- Formalize the bimoass boiler operator speciality in the education system of RA
- Involve local producers in exchange programs, leading to better pratical production skills
- Make quality the focal topic of biomass producers association development
- Involve local producers in exchange programs, leading to better pratical production skills
- Develop printed guidelines for producers and consumers of biomass fuel
- Provide transport cost compensations
- Support optimizations of supply chain with soft loans and grant
- Provide technical assistance to local producers on production matters
- Provide technical assistance to consumers on issues related to biomass boilers operations and quality of the fuel
- increase quality standards of biomass fuel
- Increase quality standards of biomass supplied to processing units
- Disseminate information about local success stories and international examples
- Promote local trading platforms advertising biomass equipment, boilers, fuel


Medium-term 2026-2030
Long-term 2031-2040
• Reduction/cancellation of import duties for biomass harvesting, transportation and production equipment
• Provide tax releif for procurement of new energy crops seedlings and plantations establishment
• Support Energy forests support program pilots
• Support lease-hire purchase of harvesting and transportation equipment
• Support lease-hire purchase of harvesting and transportation equipment
• Support lease-hire purchase of briquetting/pelleting equipment
• Monitor the operational equipment
• Involve local finacial institutions in finacing the sector
• Support commercial leasing of briquetting/pelleting equipment
• Scale up to 30 projects in public buildings with 70% grant support
• Scale up projects in private households with up to 20% grant support
• Scale up of projects in public buildings with less than 50% grant support
• Elaborate the national standards for biomass fuel quality
• Invest in modern quality control and certification equipment
• Launch a competition to identify a suitable institution for quality control and market supervision
• Organizine trainsings for boiler installers and operators
• Organize school classes dedicated to biomass fuel
• Organize summer camps dedicated to renweable energy
• Organize dedicated events to praise the best performers in the sector
• Contribute to statistical efforts to biomass consumption evidence
• Provide tax relief for producers of biomass fuel
• Provide direct/indirect subsidy to biomass supply chain stakeholders (program based)
• Support infrastructure improvement support program for business enlargements (sheds, forklifts, transporters, etc.)
• Support to energy forests program sale up
• Support to initiatives of biomass suppliers association
• Involve local producers in exchange programs, leading to better pratical production skills
• Support to initiatives of biomass fuel producers association
• Support the trading of biomass fuel via platforms, shows, etc.
• Facilitate provision of soft loans to importers and assemblers of boilers
• Scale up of projects in public buildings using the services of a private partners
• Commercial financing facilities for procurement of household biomass boilers
• Develop rapid tests for quality of biomass fuel and make them available to consumers (videos, flyers, etc.)
• Enforce the implementaiton of biomass fuel national standards in the public sector
• Organize study visits to operational boilers and production facilities for interested stakeholders
• Elaborate a curricilum for a class dedicated to renewable energy
• Modelling addtional sector needs
• Elaborate additional normative acts to support the development of the sector
• Revise incentives offered and adapt to additional needs of the sector
• Provide targeted and additional tehcnical and financial support to suppliers
• Develop a registry of suppliers and disseminate the information
• Assist the producers on matters related to warranty and technical support
• Develop a registry of trustfull producers for publication on trading portals
• Provide institutional support consumers on issues related to quality claims of fuel and/or boilers
• Supply chain logistics support to households
• Increase packaging standards of biomass supplied to processing units
• Increase transportation standards of biomass supplied to processing units
• Organize nation wide events dedicated to renewable energy

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