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Cultivation of Selected Energy Plants in Moldova

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DECLARATION

I hereby declare that the thesis on **Cultivation of Selected Energy Plants in Moldova** is my own work and that all the information sources and literature is derived from the published and unpublished works of others has been acknowledged in the text and a list of references is given.

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Prague 12th May 2008

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Abstract

This document has been written as a graduation thesis at the Institute of Tropics and Subtropics at the Czech University of Life Sciences in Prague. The topic is the Cultivation of Selected Energy Plants in Moldova.

In the first theoretical part of the thesis, there is a very short characteristic of the renewable energy sources and their share in the world energy supply. Furthermore this part is mainly focused on the importance of bioenergy, i.e. the energy produced from biomass. Types of biomass, methods of biomass conversion into different energy products are described in this part as well as benefits of the biomass energy use and limitations of its utilization.

The practical part includes a valuation of climate, soils and landscape of the Republic of Moldova and an analysis of its agriculture and energy sectors, too. After that, there is a valuation of the potential of the existing renewable energy sources in Moldova such as wind, sun, water and biomass. The core part of the thesis is focused on experimental field-tests of new energy plants growing in Moldova. It includes recommendations to the future cultivation of plants in the conditions of the republic, which were elaborated according to the collected information and experience from Moldova.

The last section of the thesis concerns an analysis and discussion of the experiment results and its comparison with a similar experiment from the Czech Republic.

Key words:
Bioenergy, biomass, energy plants, experimental cultivation, field-tests, Moldova.

Abstrakt

Tato práce byla vytvořena jako diplomová práce na Institutu tropů a subtropů na České zemědělské univerzitě v Praze. Jejím tématem je pěstování vybraných energetických rostlin v Moldavské republice.

V úvodní, teoretické časti práce je uvedená stručná charakteristika obnovitelných zdrojů energie a jejich zastoupení v celosvětové spotřebě energie. Zejména je kladen důraz na význam bioenergie, tj. energie vyrobené z biomasy. Jsou zde popsány různé druhy biomasy, metody zpracování biomasy do jiných energetických produktů, výhody energetického využití biomasy a jeho omezení.

V praktické části je charakterizována Moldavská republika z hlediska klimatu, půdy a krajiny; rovněž se zde analyzuje zemědělství a energetický sektor. Dále se práce zabývá hodnocením potenciálu existujících obnovitelných zdrojů energie v zemi, např. větru, slunce, vody a biomasy. Vetší část diplomové práce se soustředí na experimentální polní testy nových energetických rostlin pěstovaných v Moldavské republice. Tato část obsahuje doporučení pro budoucí pěstování rostlin v podmínkách dané země, které byly zpracovány na základě získaných informací a zkušeností z Moldávie.

Poslední část diplomové práce je věnována diskuzi a analýze vyhodnocení experimentálních výsledků a jejích porovnání s obdobným experimentem z České republiky.

Klíčová slova:
Bioenergie, biomasa, energetické rostliny, experimentální pěstování, polní testy, Moldavská republika.

Table of contents

1. Introduction

The Republic of Moldova is a small (33 846 km^2), landlocked and density populated country (3 581 100 inhabitants) (Statistical Yearbook, 2007). The country is situated in the Southeastern part of Europe, between the western border of Ukraine and the eastern border of Romania. It spreads on 350 km from North to South and on 120 km from West to East, on the latitude of the capital city Chisinau (is the biggest city with the population of 700 000, the next big cities are Tiraspol, Balti and Bender). The Republic is divided into 33 administrative regions plus the municipality of Chisinau, the autonomous Gagauz region and the Transdneister territory (a self proclaimed Transnistrian Moldavian Republic) (Institute of Ecology and Geography, 2005) (the map of the country is represented in the ANNEX 2, map 1).

Moldova is one of the poorest European countries. It is the agricultural country, where agriculture was always playing a very important role and was a base of national economy, employing 40 % of the country's population. The level of agricultural land use in Moldova is the highest in Europe, almost 73 % of agriculture land is arable, that makes vegetal production to be a predominant sector of agriculture.

As well as the energy sector of Moldova is substantially different from other countries. Moldova does not dispose of any natural energy sources and is almost totally dependent on both primary energy resources and electricity supply from Russian, Ukraine and Romania.

As an appropriate alternative, which can rescue Moldova from the foreign energy dependence, it seems to be the utilization of renewable energy sources. The country has significant reserves of solar energy and quit good wind and hydropower potential, but taking into account that Moldova is traditionally agricultural country and due to many other factors the biomass utilization for energy purposes, mainly agriculture residues and energy plants utilization appears as the most suitable, perspective, advanced and useful energy sources.

According my own experience from Moldova I can say that the main barrier of biomass utilization as an energy source in the country is a big lack of information and experience on the possibility of biomass energy use. And I have also noticed that people in Moldova don’t even now how to use correctly the energy they have, how to treat it well and how to economize it.

In addition to high energy potential, the cultivation and use of energy plants have great ecological benefit as well as socio-economical, it brings a positive biological and esthetical impact to the location, protects soil form erosion and other degradation processes and leads to it revitalization, that is why the growing of energy plants in Moldova is in a high focus.

Within the framework of the development project “Support Development of Study Programs at the Agriculture University in Chisinau and Coordination of its Education System with EU Standards” there were established experimental fields with energy grasses and trees in order to monitor the growing process and to expand the knowledge in energy plants, its benefits and use as a high potential energy source. It was not any analogical experiment running in Moldova before that is why the experiment has a very high importance.

2. Literature review

2. 1. Renewable energy sources, conception and development of bioenergy

Energy has always played an important role in human and economic development and in society's well being. Without the heat and electricity from fuel combustion, economic activity would be limited and restrained. Modern society became very depended on energy supply; it uses more and more energy for industry, services, homes and transport.

Anthropogenic greenhouse effect, global warming and the climate changes are nowadays reality. And the reason of these dangerous phenomena is combustion of fossil fuels, which produces the greenhouse gas carbon dioxide (CO2). According to VÁŇA, 2003 the combustion of 1 kg of black coal occurs 2,56 kg CO2, combustion of 1 kg of diesel gives off 3,12 kg of CO2 and combustion of 1 m3 of natural gas produces 2,75 kg of CO2. For the last 150 years, since the anthropomorphic discovery of fossil fuels, the carbon dioxide levels in the atmosphere have risen from around 150 ppm to 330 ppm, and are expected to double before the year 2050! (Renewable Energy Policy Project (REPP), 2005).

Intensive use of fossil fuels became unbearable for the sustainable development of human society and majority of the countries is trying to replace the largest share of fossil fuels by renewable energy sources, i.e. solar energy, wind energy, hydropower, geothermal energy, tide/wave/ocean energy and bioenergy (VÁŇA, 2003).

Descriptions of the main renewable energies based on the glossary of Energy Statistics Manual written by International Energy Agency (IEA) 2004 are the following:

Solar energy: solar radiation exploited for hot water production and electricity generation.

Wind energy: kinetic energy of wind exploited for electricity generation in wind turbines.

Hydropower: potential and kinetic energy of water converted into electricity in hydroelectric plants.

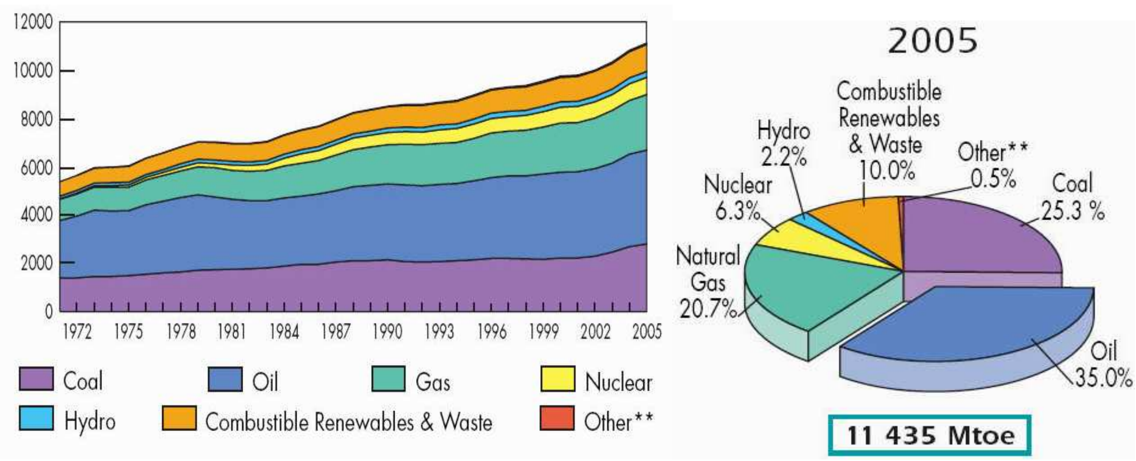
Geothermal energy: energy available as heat emitted from within the earth's crust, usually in the form of hot water or steam.

Tide/wave/ocean energy: Mechanical energy derived from tidal movement or wave motion and exploited for electricity generation.

Bioenergy: stored energy from the sun contained in biomass.

The share of energy sources in the world total energy supply and its evolution is illustrated on the **graph 1.** From the graph 1 is visible that during the last years the share and amount of renewable energies (especially bioenergy – combustible renewables and waste) were increasing.

Graph 1: Evolution from 1971 to 2005 of the world total primary energy supply* by fuel (Mtoe)



* Excludes electricity and heat trade ** Others includes solar, wind, geothermal, ect.

Source: *International Energy Agency, 2007*

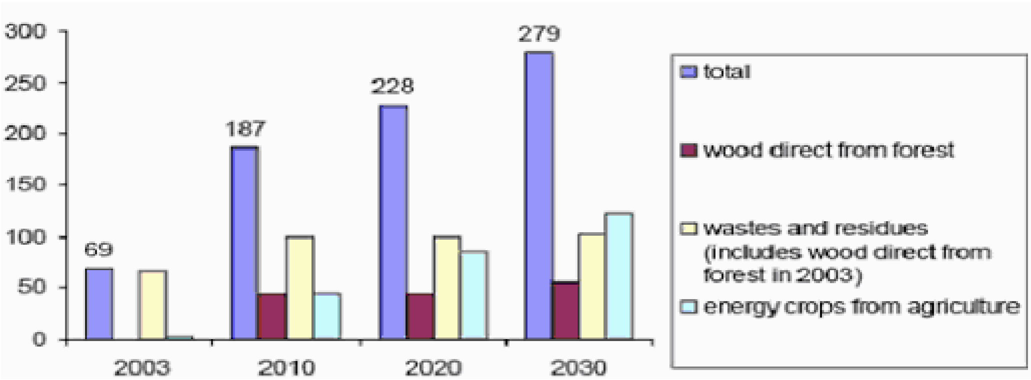
The Scandinavian countries and Austria have been the pioneering countries in the modern use of bioenergy.

Bioenergy is the most potential energy source for most of the countries. In comparison with other renewable energy sources bioenergy has a great benefit, because this source is always and everywhere available.

For example, according to European Commission document "White Paper" with the title “Energy for the future: renewable energy sources” the share of renewable energy should increase and compose 12 % of the total energy supply of European Union until the year 2010 (VÁŇA, 2003). Bioenergy should play a predominant role in this enlargement (84%). It means that the production of bioenergy will increase three times in compare with the year 2003 (HILLRING, 2003).

And it is expected that the supply of bioenergy will be growing year by year. The projection of biomass production potential on the example of European Union countries is shown on the **graph 2.**

Graph 2: EU - 25 biomass production potential (Mtoe)



Source: *COSENTINO, 2007*

2.2. Conception of biomass

Biomass is any organic matter, which is available on a renewable or recurring basis (REPP, 2005).

Biomass is the oldest known source of renewable energy - humans have been using it thousands of years since they discovered fire and started a wood burning for cooking and heating their houses.

Up to now fuelwood is the main source of energy for the people in many countries. But because of overexploitation of the forests and thanks to development of industry, breeding and biotechnologies now many other types of biomass can be used for bioenergy production.

Accordingly to the data from the graph 2 it can be concluded that these other types of biomass have already started to play an important role in biomass production.

2.2.1. Main types of biomass for energy uses:

A) Waste biomass (REPP, 2005)**:**

• **Biomass Processing Residues.** All processing of biomass yields byproducts and waste streams collectively called residues, which have significant energy potential. Still, residues are simple and cheap to use because they have already been collected.

Agricultural or crop residues are the leftovers of harvesting. They can be collected with conventional harvesting equipment while harvesting the primary crop or afterwards into pellets, chips, stacks or bales. Agriculture crop residues include corn stover (stalks and leaves), wheat straw, rice straw and processing residues such as nut hulls.

Estimated world production of the most common crop residues is presented in the **table 1.** In some areas, especially dry climates, the residues must be left to replenish the soil with nutrients for the next season and can not be completely utilized. But many regions of the world still have large untapped supplies of biomass residues, which for example could be converted into competitively priced electricity.

Table 1: Estimated world production of the most common crop residues (thousands tons of dry matter (DM))

Crop	thousands tons of DM
Wheat straw	545,000
Rice straw	350,000
Barley straw	175,000
Oat straw	60,000
Rye straw	40,000
Corn stalk	690,000
Sorghum stalk	242,000
Cotton stalk	68,000

Source: *FAOSTAT, 2005*

Forest residues (dendromass), which includes wood from forest thinning operations that reduce forest fire risk, biomass not harvested or removed from logging sites in commercial hardwood and softwood stands as well as material resulting from forest management operations such as pre-commercial thinning and removal of dead and dying trees.

- **Animal waste,** such as cattle, chicken and pig manure, can be converted to gas or burned directly for heat and power generation. In the developing world, dung cakes are used as a fuel for cooking. Furthermore, most animal wastes contain high levels of methane. Thus, this method is very unsafe, as the levels of harmful chemicals given off by the biomass are hazardous to the health of users, causing 1.6 million deaths annually in the developing nations. Since, animal wastes farms and animal processing operations create large amounts of animal wastes that constitute a complex source of organic materials with environmental consequences, utilizing the manure to produce energy properly lowers the environmental and health impacts. These wastes can be used to make many products and generate electricity through methane recovery methods and anaerobic digestion.

- **Municipal solid waste**. Residential, commercial, and institutional post-consumer wastes contain a significant proportion of plant derived organic material that constitutes a renewable energy resource.

- **Urban wood waste.** Urban wood waste generally consists of lawn and tree trimmings, whole tree trunks, wood pallets and any other construction and demolition wastes made from lumber. This rejected material can easily be collected after a construction or demolition project and turned into mulch, compost or used to fuel bioenergy plants.

Waste biomass is a high potential energy source for many countries, especially agriculture ones. And the utilization of waste biomass for energy purposes is a way to solve the problem of excess of biomass processing residues, including agricultural and forest residues, urban and animal wastes.

B) Energy plants

According to COSENTINO, 2007 **energy plants** may be defined as crops specifically cultivated to produce biomass which, for specific traits, serves as an energy vector to release energy either by direct combustion or by convention to other vectors such as biogas or liquid biofuels.

Energy plants (crops) are bioengineered to be fast-growing plants, trees or grasses which are grown as a low cost and low maintenance harvest used to make biofuels, or directly exploited for its energy content (Wikipedia). These plants can be grown, cut and replaced quickly. Energy plants are species of plants with a very high content of oils, carbohydrates or lignocelluloses.

Energy plants include (REPP, 2005)**:**

- **Agricultural crops** such as cereals, maize, sunflower, potatoes, sorghum, sugarbeet, rape, and others.

- **Energy grasses** - mostly perennials that are harvested annually after taking two to three years to reach full productivity. For example, miscanthus, topinambur, reed canary grass, malva, sorrel of Uteush, bamboo, tall fescue, kochia, wheat-grass, and others.

- **Energy trees,** short-rotation woody plants and fast growing trees harvested within three to six years after planting. These include hybrid poplar, hybrid willow, silver maple, eastern cottonwood, green ash, black walnut, and acacia.

Accordingly to Database of information about renewable energy recourses DAZA it was indicated about 100 plants around the world, which could be suitable for energy use. The choice of energy plant depends on many factors such as soil and climate condition of the location, existing agriculture machinery and equipment for planting, harvesting, processing and transportation, it depends on the method of use and country needs, etc.

Plant ideotype for energy production (COSENTINO, 2007)

An energy crop should gather the following characteristics:

- Fast grow
- High dry matter and biomass yield
- Specifically developed for an environment
- Able to utilize available natural resources
- Resistant to biotic stress (pests, diseases, weeds)
- Resistant to abiotic stress (water, low and high temperature, salt)
- Quality traits specific for each different use (biogas, biodiesel, bioethanol, etc.)
- Above growing biomass (harvesting of the top part is lower price and protects the soil)
- Highly positive energy balance
- Environmentally friendly
- Low content of elements, especially N. Ashes makes worse the fuel quality.

The cultivation of perennial energy grasses and trees is usually more effective then cultivation of annual plants from economic and energy points of view. The cultivation of perennial plants decreases the total cost of biomass unit production and increase the share of energy output in comparison with input (output can be 4-10 times higher then input). It is because the cultivation of perennial plants require the biggest economical inputs in the first year of the plantation establishment (these inputs can be even higher then for traditional agriculture annual crops). But in the following years the inputs for perennial plants cultivation are collapsing, because there is no need of inputs for soil preparation, planting or sowing, the inputs for fertilizers and chemicals are declining and drawing to a zero (WEGER, 1996).

The main and the most important characteristics of energy plants as energy sources are the **yield of dry matter**, **heating value** and **energy yield**. Below there is a **table 2**, which lists different energy plants and their energy characteristics.

From the table 2 is evident that plants with higher yield of dry matter usually have higher heating value and energy yield, so their cultivation is more profitable.

It is commonly considered that plants, which yield about 12 t.ha-1 of dry matter, are of "energy" consequence. However, the cultivation of some plants, for example reed canary grass or false flax, is economically effective too, in spite of smaller yield of dry matter (STRAŠIL, 1999).

Table 2: Energy characteristics of different energy plants (comparison with straw of cereals and fossil fuels)

Plant	**Average yield of DM (t.ha-1)**	**Heating value (MJ.kg-1)**	**Energy yield (GJ.ha-1)**
Sorrel of Uteush 2)	14-16	18, 5	278
Miscanthus 1)	15,00	17,89	268,3
Malva 4)	10-15	17, 58	235, 58
Sorghum Hyso	16	17,67	282,51
Sweet sorghum 1)	11,48	17,59	201,9
Corn sorghum 1)	5,78	17,63	101,9
Hemp 1)	10,52	18,06	190,0
Topinambur 2)	5 – 48	18,03	-
Poplar(different clones)	15,6-21,2 6)	18,7–19,2 3)	150 5)
Willow(different clones)	8,9-10,1 6)	18,2–19,0 3)	150 5)
Reed canary grass 2)	4,5 - 9,0	17,52	140,5
False flax 1)	4,71	18,84	88,9
Rapeseed (straw) 1)	4,74	17,48	82,8
Sunflower (straw) 1)	8,31	16,70	38,8
comparison:			
Cereals (straw) 1)	4,50	15,20	68,4
Natural gas 3)		33,50	
Black coal 3)		28,00	
Brown coal 1)		8,00 – 16,00	

Sources: *1) STRAŠIL a kol, 1994, 2) KÁRA a kol., 2005, 3) KOUTSKÝ & al., 2001, 4) PETŘÍKOVÁ, 1997, 5) Kolektiv řešitelů, 2006, 6) ŠINKORA, 2008*

Straw of cereals has low heating value and low energy yield in comparison with energy plants, but counting the fact that straw is byproduct, its utilization for energy purposes is important and very useful.

From the table 2 is visible that heating value of dry matter of listed energy plants is even higher then heating value of brown coal.

The moisture (dry matter content) is very important parameter of biomass. And it has a significant impact on energy characteristics of biomass. **Table 3** shows impact of moisture on the heating value of biomass in the form of woodchip.

Table 3: Impact of moisture to the heating value of biomass

Biomass	**Moisture**	**Heating value (MJ.kg-1)**
woodchip	60 %	9,20
woodchip	40 %	10,10
woodchip	30 %	12,20
woodchip	20 %	14,30

Source: *KOUTSKÝ & al., 2001*

2.2.2. Biomass energy products, methods of biomass convention into energy

Biomass energy products:

Biomass can be used in a variety of energy conversion processes in order to yield the following products:

1) **Power** (electricity)
2) **Heat**
3) **Steam**
4) **Fuel** (solid or liquid)

Conversion methods

The method of biomass conversion into energy is mainly predetermined by physical and chemical character of biomass, first of all by its moisture. The rate 50 % of dry matter is approximate border between wet (dry matter content is less then 50 %) and dry (dry matter content is more then 50 %) methods/processes. From the principal viewpoint, there are several methods of energy production from biomass and biomass preparation for energy use can be distinguished (PASTOREK i kol., 2008):

A) Thermo – chemical convention methods (dry processes for biomass energy use)

* **Combustion.** Most of the biopower plants in the world use a direct-fired system or a conventional steam boiler. Both systems burn biomass directly to produce steam which in turn creates electricity. Differences in the methods lie within the boiler or furnace structure. In a direct-fired system, biomass is loaded in from the bottom of the boiler and air is supplied at the base. In a conventional steam boiler, the draft is forced in through the top but the biomass is also bottom loaded. Traditional direct-fired systems are the pile system (which uses a two-chamber combustion chamber) or the stoker boiler. Hot combustion gases are passed through a heat exchanger in which water is boiled to create steam. This steam is usually captured by a turbine, causing the turbine blades to rotate. The rotation is attached to an electrical generator, which then creates electricity (VÁŇA i kol., 2008).

Biomass can be added to a furnace or a boiler to generate heat which is then run through a turbine which drives an electrical generator. The heat generated by the exothermic process of combustion to power the generator can also be used to regulate temperature of the plant and other buildings, making the whole process much more efficient. A plant using this type of technology is called a combined heat and power (CHP) facility and as its name suggests, it uses both the heat and the steam, so that there is less potential energy wasted (REPP, 2005) (see ANNEX 1, schema 1: direct combustion/steam turbine system).

*** Co-firing.** Co-firing, combining biomass with coal to generate energy, is probably the most compatible way to use biomass with the current fossil fuel dependent system. With co-firing, woody and herbaceous biomass can fuel a small portion of an existing coal power plant. This process entails biomass that represents between 1% and 15% of the energy of the coal plant, with the remainder consisting of coal. In these systems, biomass is placed into the boilers and burned, as coal would be. Often the only cost associated with upgrading the system to burn both fuels is to purchase a boiler capable of doing so, and retrofitting it into the system, which is a whole lot cheaper than building a whole other plant.

There are several environmental benefits of adding biomass to coal, including decreases in nitrogen and sulphur oxides, the causes of smog, acid rain and ozone pollution. Also, the amount of carbon dioxide released is also considerably less. Though other methods of bioenergy have the same benefits too, with even lower (a theoretical net of zero) carbon dioxide emissions. In other words, co-firing appears to be a wonderful option for immediate use and a good stepping stone towards more viable and sustainable renewable energy practices (IEA, 2004).

* **Pyrolysis.** Pyrolysis is a process where biomass is combusted at high temperatures and decomposed in the absence of oxygen. However, some difficulties arises when trying to create a totally oxygen free atmosphere. Often a little oxidation does occur which may create undesirable byproducts and also it is highly energy intensive and expensive at the moment. The burning creates pyrolysis oil, char or syngas which can then be used like petroleum to generate electricity. It does not create ash or energy directly. Instead it morphs the biomass into higher quality fuel. The process begins with a drying process in order to maximize burning potential from the biomass, similar to the direct combustion process above. When cooled, the brown liquidly pyrolysis oil can be used in a gasifier (VÁŇA i kol., 2008).

*** Biomass gasification**. Solid biomass can be converted into a gaseous form, known as syngas. The gas then can run through "combined-cycle" gas turbine or another power conversion technology such as a coal power plant. Biomass gasifiers operate by heating biomass in an environment where the solid biomass breaks down to form a flammable gas. This offers advantages over directly burning the biomass. The biogas can be cleaned and filtered to remove problem chemical compounds. The gas can be used in more efficient power generation systems called combined-cycles, which combine gas turbines and steam turbines to produce electricity. The efficiency of these systems can reach 60% (see ANNEX 1, schema 2: biomass gasification).

First the fuel is placed into the gasifier, where it is turned into a hot pressurized combustion gas. Then it is fed thorough a gas cleaner to precipitate out elements that would corrode the system. These elements vary depending on the source burned. The cleaned gases are then combusted and used to spin a turbine, which generates electricity. Heat released from the gas in the turbine can be recovered using water in the heat exchanger. The hot water can be recycled through the system. The only other byproduct is non-toxic ash, which could, for example, be mixed with compost to help grow more biomass fuel (REPP, 2005).

B) Biochemical convention methods (wet processes for biomass energy use):

*** Alcoholic fermentation.** In alcohol fermentation, the starch in organic matter is converted to sugar by heating. This sugar is then fermented by yeast and some kinds of bacteria. These microorganisms convert sugars in ethyl alcohol and carbon dioxide. Alcoholic fermentation begins after glucose enters the cell. The glucose is broken down into pyruvic acid. This pyruvic acid is then converted to CO2, energy and ethanol (known as ethyl alcohol or bioethanol) (KOŠÍKOVÁ, BUČKO, 1999). Ethanol is produced through fermentation at either a dry mill or at a wet mill. The dry mill process is simpler than the wet mill process. The wet mill breaks the biomass into its components and processes each separately. In addition to ethanol, both processes also create distiller's grain, which is fed to farm animals.

Up to 24% ethanol can be added to gasoline before engine modifications are necessary. A blend known as E85, which is 85% ethanol and 15% gasoline, can be used to power flexible fuel vehicles (FFVs). Many cars on the market today are already built to run on E85. Brazil has had much success converting nearly all of its vehicles to run on E85 made from sugar.

Ethanol has a better environmental profile than gasoline as measured at both the production facility and the tailpipe. Ethanol production plants produce less carbon dioxide, methane and particulates than gasoline refineries, which help meet clean air standards. A blend of 10% ethanol, or E10, yields a 26% reduction in greenhouse gases when compared to gasoline alone (REPP, 2005).

The **table 4** represents the most used crops for bioethanol production, their yield, alcoholic yield and the amount of produced ethanol.

Table 4: The ethanol production from different crops

Crop	**Yield t.ha-1**	**Alcohol yield l.t-1**	**Ethanol production l.ha-1 (t.ha-1)**
Sugarbeet (root)	35 – 45	80	2 800 - 3 600 (2,3 - 2,9)
Sweet sorghum (above growing biomass)	30	76	2 280 (1,8)
Topinambur (tuber)	30	77	2 310 (1,9)
Potatoes (tuber)	20 - 30	100	2 000 - 3 000 (1,6 - 2,4)
Winter wheat (grain)	5 - 6	370	1 850 - 2 22O (1,5 - 1,8)
Maize (corn)	3,4 - 4,5	386	1 312 - 1 737 (1,1 - 1,41)

Source: *KÁRA, J. a kol, 1995*

*** Anaerobic digestion** is a biological process, where the methane released by the synergistic actions between bacteria and archaea are contained and used to create energy. Anaerobic Digestion uses biowaste such as manure and municipal solid waste (MSW) as feedstocks. This biomass is bagged and broken down by using bacteria and water. This process releases the methane in the bag, and it is siphoned off into another holding bag. From there, the gas is used to power turbines which generate electricity.

At the molecular level, hydrolysis converts a wide range of solid organic materials into sugars and amino acids. Fermenting these materials produces volatile fatty acids (VFAs). Then the VFAs form hydrogen, carbon dioxide, and acetate through

Acidogenesis. Finally, methanogenesis produces biogas, a mixture of 55-70 % methane, 25%-35% carbon dioxide, and trace elements of nitrogen and hydrogen sulfide. Conducted in an airless environment, the methane can be captured and used to power a gas turbine or even fuel cells (VÁŇA, SLEJŠKA, 1998).

It was found what the production of biogas from vegetable or plant biomass is 50-70% more effective then form animal wastes (REPP, 2005). Together with biogas production the stable organic fertilizer is produced and returned back to agricultural process. Big amount of carbon remains in the solid reminder and isn’t going to the atmosphere like during the combustion and it is a very important factor and benefit of biogas. And also biogas has a high caloric value 20 - 24 MJ.m-3 (PASTOREK, WOLFF, 1993).

C) Mechanical – chemical convention methods:

*** Crushing, pressing, briquetting, pelleting, milling**, etc. The result of these processes is the production of solid biofuels. All the processes lead to biomass modification aiming to improve handling and combustion characteristics (REPP, 2005). Nowadays the numbers of equipments such as different crushers, hogging machines, briquetting and pelleting are available. Simple biofuels in the forms of bales, wood chips, chaffs or short-woods are widely produced from plant biomass. Due to densification process of loose organic material (briquetting or pelleting) is possible to produce the better – quality biofuels in the form of briquettes and pellets with a higher fuel value. The composition of these better – quality biofuels and can be presented by single source of biomass (for example, only wood or only straw) or can be combined with different types of biomass or with coal (KÁRA, HUTLA, STRAŠIL, 2003).

Picture 1. is illustrated different forms of solid biofuels and different types of briquettes.

Picture 1: Forms of solid biofuels and different types of briquettes

a) forms of biofuels b) type of briquettes

* **Esterification** of organically derived oils or fats (production of biodiesel and natural lubricants). Esterification is the general name for a chemical reaction in which two reactants (typically an alcohol and an acid) form an ester as the reaction product (Wikipedia).

Biodiesel is the result of combining alcohol (including ethanol) with oil extracted from soybeans, rapeseed or other biomass. Biodiesel like traditional diesel is successfully used in the car engines, but it burns much cleaner, what is making it more environmentally friendly. And biodiesel production is also low cost (REPP, 2005).

D) Waste heat extraction at biomass processing (for example at composting, aerobic water cleaning, anaerobic fermentation of solid organic wastes and etc.) (PASTOREK i kol., 2008).

In spite of many biomass convention methods existence, the biomass combustion is the most used method from the dry methods of biomass convention to energy and biogas production by anaerobic digestion predominates in practice from the other wet convention methods (PASTOREK, KÁRA, JEVIČ, 2004).

2.2.3. Benefits of biomass use for energy purposes and limitations of its utilization

The energy use of biomass has undisputed **benefits** for the environment, agricultural sector, for increase of community and nation prosperity, and many others:

- Biomass is renewable resource - it can be replaced fairly quickly without permanently depleting the Earth's natural resources. By comparison, fossil fuels such as natural gas and coal require millions of years of natural processes to be produced. Therefore, mining coal and natural gas depletes the Earth's resources for thousands of generations. Alternatively, biomass can easily be grown or collected, utilized and replaced (REPP, 2005).
- The big advantage is that sources of biomass are not locally limited.
- The greatest benefit of biomass and the important reason why science and people throughout the world are interested in new, renewable plant materials is their positive environmental impact, due to their natural ability to make use of CO2 to build their tissue. Furthermore, emissions of harmful gasses (CO, CO2, SOx, NOx) and ash that contribute to the greenhouse effect are significantly lower when plant materials are used to produce energy instead of fossil fuels. This is possible because producing energy from biomass is a natural and almost closed cycle, where even ash, a product of combustion, can return to the fields as fertilizer with a good nutrient content of Ca, Mg, K and P. Indeed, modern bio-energy technologies and bio-fuels produce very little pollution if they are burnt correctly and completely. Biomass could produce alternative to fossil fuels products, but at a lower environmental cost (VÁŇA, 2003).
- The use of bioenergy provides the opportunity for local, regional, and national energy self-sufficiency across the globe (REPP, 2005).
- Recent overproduction problem of agriculture could be reduced by cultivation of plants with energy purposes. And from the other side energy plants can be cultivated and grow well on non-agricultural land.
- The land which is over limit contaminated by extraneous substances and is not suitable for agriculture crops cultivation can be used for energy plant growing. Growing of energy plants on such lands contributes to revitalization of these lands in a long term period (VÁŇA, 2003).
- The biomass convention into energy is a good opportunity, ecological and very effective way for elimination agricultural residues, crop byproducts and waste, which are originated as a result of people activities (it means that combustion and sometimes toxic wastes can be utilized purposely).

- Biomass grown as dedicated energy crops can provide new economic opportunities especially for farmers and forest owners (IEA, 2007).

The theoretical reanalysis of different experts shows that the world production of biomass is about 100 billions tons per year, so its energy yield is 1 400 EJ. It is more than five times more then the world annual energy supply of fossil fuels (300 EJ). Why does the biomass utilization for energy purpose and solving of the global problem is still **limited**? (PASTOREK i kol., 2008)

- Production of biomass for energy purposes competes with the other purposes of biomass utilization (for example, for food and feed processing, for industrial uses, etc.)
- In order to increasing of biomass production is necessary to expand the productive lands or the increase the intensity of biomass production, this will lead to higher contribution of capital to biomass production.
- Production of energy from biomass economically competes with the utilization of classic fossil energy sources with difficulties. This real fact can be gradually changed under the influence of ecological legislative. Specific biomass content and properties require the special construction of boilers for biomass processing. The boilers are nowadays technically and technologically constructed, but their price is higher then the price of boilers for fossil fuels.

In my opinion one of the biggest barriers for utilization of biomass for energy purposes is the lack of information, knowledge and experience in the field of bioenergy in many countries, mainly in developing ones.

3. Objectives

The main objective of the thesis is to start field-tests of new energy plants growing in Moldova in order to monitor the growing process. The next important objective is to analyze the grow parameters of both energy grasses and tress and to elaborate the recommendations to future cultivation and harvesting and to valuate their advantages as the energy source as well.

In order to fulfil the main objectives the following specific objectives are necessary:

- to valuate the climate, soil and landscape conditions of Moldova,
- to analyze the agriculture and energy situation of the county,
- to evaluate the situation of existing renewable energy resources in Moldova and its possible use in energy purposes.

This thesis should be taken as an information background for those, who wants to expand the knowledge about biomass utilization for the energy purposes and for those, who plans to grow the energy plants in the conditions of the Republic of Moldova.

I have put a special accent to the recency of the information; all the data in this thesis are as actually as possible.

4. Methodology

In order to fulfil the above-stated objectives the following methodology and methods were used:

4.1. Information gathering in Moldova

In order to fulfil the main and specific objectives of the thesis the data and information on Moldavian climate, soil, landscape, agriculture and energy sectors were collected from the various institutions and Ministries in Moldova such as the Research Institute for Mechanization and Electrification of Agriculture “Mecagro”, Research Institute of Soil Sciences and Agrochemistry “N.Dimo”, Institute for Plant Protection and Ecological Agriculture and Ministry of Ecology and Natural Resources, National Agency for Rural Development and The State Agriculture University in Moldova.

4.2. Analysis of information collected in Moldova

On the base of all collected data and information and its comparison there was made an analysis of Moldavian renewable energy sources potential. All existing in Moldova renewable energy sources, such as wind and solar energy, hydropower, energy of geothermal recourses and biomass were valuated, their potential was estimated and the barriers for the utilization were explained.

4.3. Information gathering in Czech Republic

In order to fulfil the main and specific objectives of the thesis it was high necessity to collect the information about the biomass, its uses, types, methods of its conversion direct into the energy or into the every vectors, etc. and it was also very important to collect a lot of the information about energy plants, its biological characteristics, soil and climate requirements, about the methods of planting, harvesting and utilization. Due to the lack of such information in Moldova, the information was collected in Czech Republic, mainly from the Research Institutes of Crop Production in

Prague and Chomutov, Research Institute of Agriculture Technology in Prague, The Silva Taroucy Research Institute for Landscape and Ornamental Gardening in Průhonice, from Food and Agriculture Library in Prague and from internet sites such as BIOM.CZ, Wikipedia and others.

4.4. Analysis of information collected in Czech Republic

On the base of information collected in Czech Republic together with the information about Moldavian climate, soil and landscape that was collected there, there was made an evaluation and were given advantages of chosen energy crops; and further there were developed the recommendations on its planting, harvesting and future cultivation in Moldova.

4.5. Establishment of the experimental field

First energy plants including energy grasses and fast-growing tress were brought from the Czech Republic and plant on the experimental fields of the Moldavian State Agricultural University in Chisinau in the middle of April 2007. Later in the middle of May and in the middle of September the other spices of energy grasses were planted as well. The planting (sowing) was done manually according to instructions and subsoil ploughing was done before planting (sowing). From the beginning it was agreed to cultivate all these plants with the minimum economic inputs: not any chemical of mechanical treatment and even irrigation has been expected.

4.6. Field monitoring, elaborations and descusion of results, formulation of recommendations

Five monitoring were done during the year. The main grow parameter of the energy plants such as high, survival, number and thickness of the stem shoots were monitored, measured, analyzed, statistically elaborated and presented in the form of graphs. Later the results were compared with the results of similar experiment done in Czech Republic. At the end of the thesis the recommendations were formulated.

5. Results and Discussion

5.1. Valuation of climate, soil condition and landscape of Moldova

5.1.1. Climate conditions

The Republic of Moldova has temperate-continental climate, relatively mild winters with average daily temperature -3.5°C and little snow, as well as warm summers with average daily temperature +21.4°C and with limited rainfall. The warm period lasts for 260-290 days; the cold one is relatively short 75-150 days (Ministry of Environment and Natural Resources, 2007). The atmospheric circulation is characterized by the movement of cool air from the Atlantic Ocean zone eastwards and the movement of the warm and humid air from the Mediterranean Sea. Sometimes, an inflow of relatively cold and dry air intervenes from the northern latitudes.

The territory of Republic belongs to not humid enough. According to information form the net of meteorological stations Goskomhydrometeo, the average annual precipitation reduce by intensity from the north-west to the south-east, with very big amplitudes between the years: deviation from the norm to one or another side can be double and more.

Table 5: Average annual temperature and precipitation in 2006, as compared to multiannual values in different regions of the Republic of Moldova

Region (station)	Average temperature, °C		Average precipitation, mm	
	multiannual	year 2006	multiannual	year 2006
North (Briceni)	7,8	8,5	617	684
Centre (Chisinau)	9,5	10,2	523	564
South (Cahul)	10,0	10,8	521	367

Source: *Institute of Ecology and Geography, 2007.*

The rainfall is erratic, about 75-80 % of precipitation is typical for warm period of the year. Long not intensive rains good for soil irrigation can occur at this period, but predominate and specific for the region are torrential very intensive rains, which have a negative impact to soil condition (torrential rains affect about 80 % of agricultural land).

According to the Centre for Epidemiologic Studies of Natural Hazards (Belgium), the most frequent natural hazards occurring in Moldova are floods (as result of torrential rains, 1-2 events per decade), draughts (2-4 events per decade), strong winds, tornadoes, hails, spring and autumn frost and earthquakes.

5.1.2. State of soils

The Republic of Moldova is endowed with fertile soils. Chernozems cover almost three quarters of the total land area.

Agriculture had a deep impact on the soil processes, through changing the balance of organic substances, the thermal and water regime, and the nutrients turnover. The fertility of Moldovan soils suffered along the last two centuries of intensive agriculture, but the processes of soil degradation particularly increased in the XX century and have been exacerbated during the last 10-15 years. Disturbed crop rotation and dropped application of mineral and organic fertilizers resulted in a significant negative balance of humus and nutrients in the soils and leaded to their biological degradation.

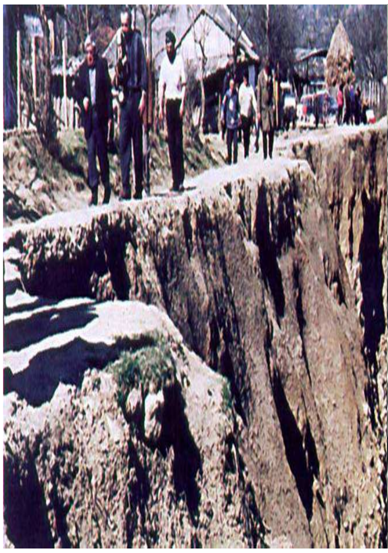
The main ***soil degradation processes*** in Moldova are: soil destructuring, compaction, dehumification, erosion, landslides, salinization, alcalinization, waterlogging. Their propagation is enhanced by human activities and is favoured by landscape and climate peculiarities.

During the last 30 years the normal arable soils have lost on average 10% of their productivity through intense ***dehumification*** (the gradual loss of soil humus content). The main cause for the negative balance of humus in the topsoil is that harvesting is not compensating the removal of organic substances from the soil by harvesting. The only way to prevent dehumification and maintain soil fertility is to restore the amount of nutrients extracted, by using all local sources of organic substances available, manure first and foremost.

The geological structure (alternation of permeable and impermeable layers) along with a specific hydrologic regime is contributing to increased activity of ***landslides***. The total area affected by the landslides is 55,500 ha. The most affected is the central part of the country. During the last years, the area of landslides enlarged annually by 1000 ha (Institute of Ecology and Geography, 2007).

Below there are represented the **pictures** of Moldavian soils affected by some degradation processes.

Picture 2: Landslides



Picture 3: Soil erosion

Picture 4: Waterlogging

Source: Managementul Riscurilor Dezastrelor in Republica Moldova, 2006

The region is often affected by droughts. Irrigation has long been used for ensuring a stable agriculture output. In Soviet times irrigation systems have been created on 230,000 ha (presently only a minor part of these are being irrigated). Irrigation leaded to soil ***destructuring, compaction, salinization*** and ***alcalinization*** on large areas. The productivity of such lands is on average 30% lower (Economic Commission for Europe, 1998)

Erosion is a real "cancer" of Moldovan soils. According to last evaluations, the area of lands affected by erosion exceeds 850,000 hectares or approximately 35% of agriculture land. On average, some 26 million tons of fertile soil is lost annually from agriculture lands. The rapid soil erosion has serious implication for the long-term sustainability of agricultural production in Moldova. The indirect damage from erosion refers to: siltation of water bodies; pollution of soils and groundwater with agri-chemicals washed out from the fields; destruction of roads and hydrotechnical works, etc. The total annual economic losses from erosion are estimated at approximately US$ 200 million (Ministry of Environment and Natural Resources, 2007). The main factors contributing to the intensification of erosion processes are: large share of land converted into arable; deforestation (esp. forest belts); improper tillage practices; exaggerated share of several crops (e.g. corn, sunflower) in agriculture production, etc. The landscape has a major influence on the forms and intensity of erosion. The only way to effectively curb soil erosion is to approach the problem systemically in the sense that the entire agriculture (land planning, location and geometry of fields, crop rotations, tillage methods) has to be organized according to anti-erosional principles. Currently almost no anti-erosion activities are undertaken.

5.1.3. Landscape and landscape diversity

The Republic's landscape is generally hilly, gradually sloping from the north-west to the south-east, with altitudes varying between 5 and 429, 5 m. The average elevation is 147 m above sea level. Slopes account for 57 % of the total country area (The World Bank, 2004).

According to the Institute of Ecology and Geography of Moldova, the country possesses diverse landscapes: five distinct landscapes are recognized within the two main natural zones: steppe and forest - steppe vegetation (**see picture 5**).

The steppe zone has undergone big changes, its vegetation being practically destroyed. Its area decreased drastically during the 19th century, when vast area was ploughed to cultivate cereals as its soil was fertile. Nowadays the steppes in southern and southeastern Moldova are characterized by low precipitation, dry winds and occasional drought. The dominant species are now grasses with typical Mediterranean representatives (*Stipa* sp., *Bothriocloa* sp. and *Festuca* sp.), although the native steppe historically included many *Artemisia* species. The steppe also contains forest elements such as oak (*Quercus pubescens* and *Querus robur*). The steppe zone is divided into two landscape regions. The steppe plains of the Lower Nistru terraces in south-east Moldova cover 19 % of the republic's surface area. These are strongly impacted by human activities, but are still rich in species typical of steppe communities. The west steppe of the Nistru rivet also contains oak (*Quercus pubescens*) groves. The Bugeac steppe plains of south-west Moldova cover 20 % of the republic, and contain grass species adapted to xeric conditions there, as well as several oak species (*Quercus pubescens, Q. robur, Q. petraea*) (Institute of Ecology and Geography, 2005).

The steppe and meadow herbaceous host 790 species of vascular plants, out of which 30 rare species have been included in the Red Book of the Republic of Moldova (second edition).

Picture 5: Natural zones and landscape regions

Forest – steppe zone

Region of plateaus and forest steppe plateau

Region of plateaus and plains with meadows of Bãlti steppe

Region of plateaus with forests of Codrii

Steppe zone

Region of the steppe plain of he Lower Nistru river terraces

Region of fragmented plains of Bugeac steppe

Source: *Ministry of Ecology, Construction and Territorial Development, 2002.*

The forest- steppe zone of northern and central Moldova includes different forests (e.g., oak, beech etc.), steppe and riverine meadow biotopes within a landscape dominated by plains and plateus. Three landscape regions are found in the forest – steppe zone:

A – Plateaus of forest – steppe in north – eastern Moldova cover about 23, 8 % of the country. The landscape is characterized by plateaus and hillocks dominated by oak

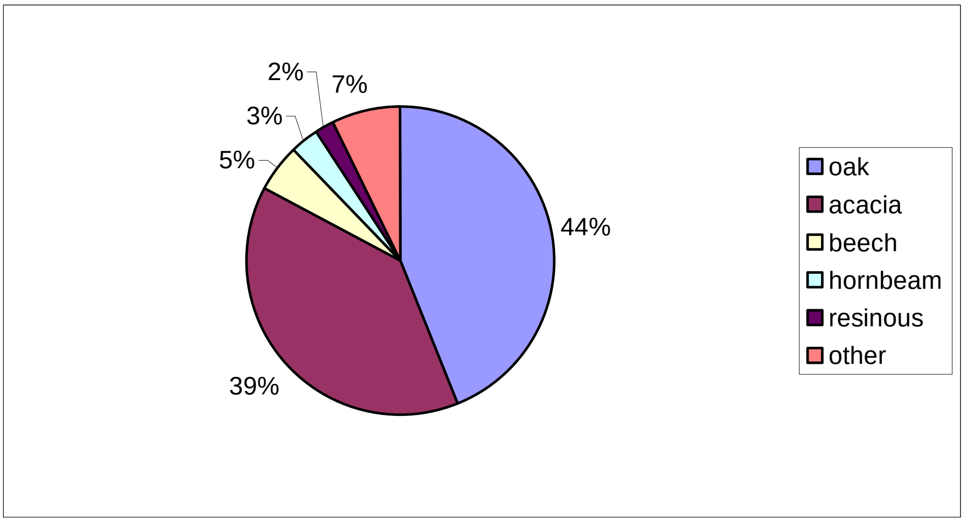
(*Quercus*) forests, valleys with willow (*Salix*) and poplar (*Populus*), steppe and meadow formations.

B – The plateau and plain region of Bãlti steppe in the north of Moldova covers 20, 6% of the country. The landscapes are represented by natural territorial complexes of hillocks as well as by slopes from river valleys; the forest vegetation is represented by *Quercus* sp. formations with *Prunus ceresus*; the meadow vegetation is represented by steppe and river meadow communities (*Stipa*, *Festuca*, *Deschampsia*).

C- The plateau of Codrii forests is in the central Moldova and covers over 15 % of the republic. The landscape is predominantly natural, with rounded mountain-tops and ancient landslides. The forests are mainly beech (*Fagus* sp) and oak (*Quercus petraea*, *Quercus robur*), with herbaceous understory dominated by species typical of Central and East_Europe (*Aegopodium*, *Dactylus*, and *Carex*) (Ministry of Ecology, Construction and Territorial Development, 2002).

Moldovan forests host 1008 species of vascular plants out of which 60 species have been included in the Red Book of the Republic of Moldova. Distribution of forests by species is shown on the **graph 3**.

Graph 3: Distribution of forests by species



Source: *Ministry of Ecology, Construction and Territorial Development, 2002.*

The Republic of Moldova has 422,200 ha of forests covering 11.1% from the country's territory (Ministry of Environment and Natural Resources, 2007), which is a very low figure as compared to the European average (29%) or the countries of the same biogeography region – Romania (28%), Bulgaria (35%) or even Hungary (19.5%).

Three centuries ago, the territory between the Dniester river and the Prut river had a 30% forest coverage. In the XIX century, extensive areas were brought under agriculture land-use, largely at the expense of the forests. The change forest territory in the Republic from the year 1848 until 2006 is represented in the **table 6**.

Table 6: Forest cover on the territory of Moldova (in thousands of ha)

Year	**1848**	**1918**	**1945**	**1973**	**1983**	**1993**	**2004**	**2005**	**2006**
Forested areas	366,2	230	222	271,2	301,2	333,9	362,1	373,8	422,2

Source: *Ministry of Environment and Natural Resources, 2007.*

86.7% of the forestry stock is in administration of „Moldsilva" Silviculture Agency, 12.8% – local public authorities, 0.5% – Ministry of Transportation and Road Management, Ministry of Defense and other holders. Only 400 ha of forests are private.

Forests are an important stabilizing factor for the environment. They should be managed well and the forest area should be increased in order to preserve biodiversity, to stabilize land threatened by erosion and landslides and to protect water resources. To maintain the ecological balance it is necessary for the forest areas to exceed 15%.

5.2. Analysis of Agriculture of the Republic of Moldova

5.2.1. The agricultural sector in transition

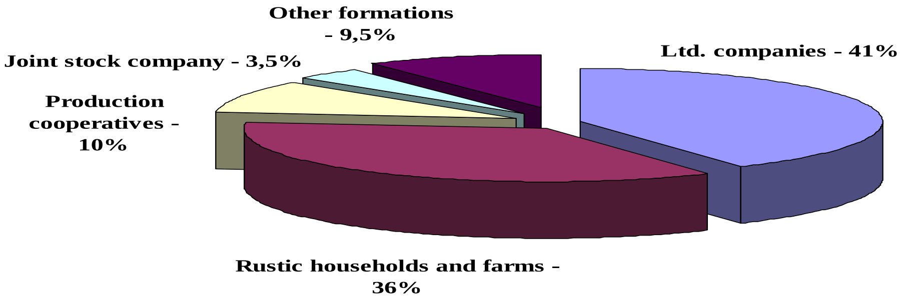
Until about 1945-50, the territory of Moldova was intensively cultivated. Farmers' plots were small – between 5 and 7 ha on average – but the country was self – sufficient in agricultural produce. Farmers favoured mixed production in orchards, gardens and pastures. The comparatively high share of grassland effectively precluded substantial erosion. The organization of the agricultural sector involved agricultural chambers, which supplied farmers with seed and other material. An agricultural bank granted loans at reasonable interest rates on tide farmers over (Economic Commission for Europe, 1998).

With the process of collectivization in the former Soviet Union (in Moldova later than in other Soviet republics), all those institutions were disbanded, and bigger, more economically viable units (kolkhozes and sovkhozes) were created. Monoculture and intensive technologies displaces traditional agricultural practices. Almost all grassland was turned into arable land. Also, steppes were cultivated. Moldova's big collective farms specialized in certain types of produce and were relatively well – equipped, compared to other in the Soviet Union. They were considered as an agricultural testing and development area. All new technologies were first implemented here, and selection stations supplied the rest of the Soviet Union with seeds of indigenous species (particularly maize). Until the late eighties, Moldovan agriculture was a powerful economic sector.

After privatization in the 1990s, a large share of land remained atomized in small individual plots. There were more than 1.3 million landowners. The privatization process resulted in an average landholding of 1.4 ha, often divided into more plots. In many cases it was not possible to use these small plots efficiently. Production of many traditional crops such as grain, sunflower or sugar beet is dependent on mechanization, and therefore can be performed only on bigger areas. In addition, the new farmers and owners lack experience, technical skills and finances to develop their production successfully. As well as over the 1990s Moldova's agriculture and food industry have faced a series of shocks, including a large deterioration in the terms of trade and severe droughts. A drastic reduction in input of capital into agriculture has gone hand in hand with a significant decline in production (Economic Commission for Europe, 1998).

Nowadays approximately one third of the land is under small farms of maximum 2-3 ha. The rest of agriculture land was consolidated to various extents and in various forms (e.g. leasing, cooperatives, farmers associations, etc). There is a structure of farmsteads holding agricultural land in breakdown by category on the **graph 4**.

Graph 4: Structure of farmsteads holding agricultural land in breakdown by category

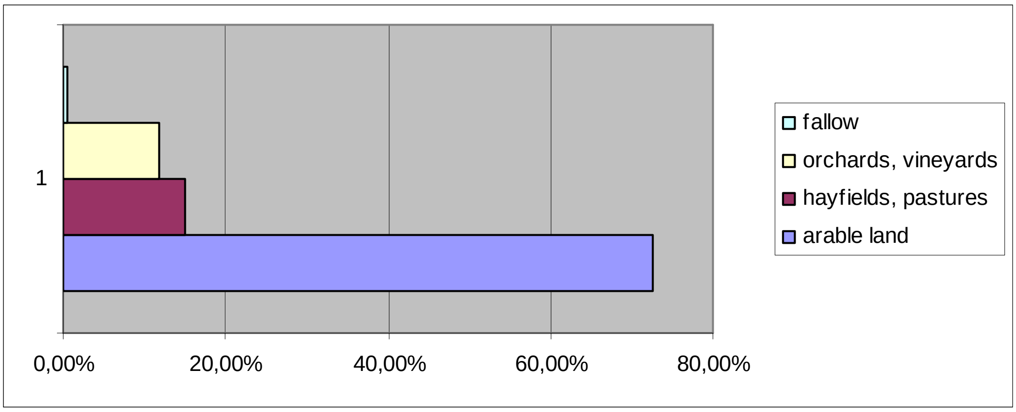


***Source**: Land and Cadastral Agency of the Republic of Moldova*

In the Republic of Moldova agriculture has been traditionally regarded as the cornerstone of the national economy: agricultural output accounts for 15% of GDP and together with the processing industry represents over 30% of GDP and approximately 50% of total exports. At the same time, agriculture constitutes the most important sector of the national economy, using over 40% of country's labor force about 4.3.millions people (54% of the country's population lives in the rural areas where almost all of the labor force is engaged in agriculture) (The World Bank, 2004).

The total agricultural lands cover 2.518.200 ha or 74.4 %, out of which 1.833.200 ha arable land, 298.700 ha orchards and vineyards, 370.200 ha hayfields and pastures, 16.000 ha fallow (see **graph 5**). The level of agriculture land use in Moldova is the highest in Europe.

Graph 5: Structure of agriculture land use in Moldova (in %)



***Source:** Institute of Ecology and Geography, 2005.*

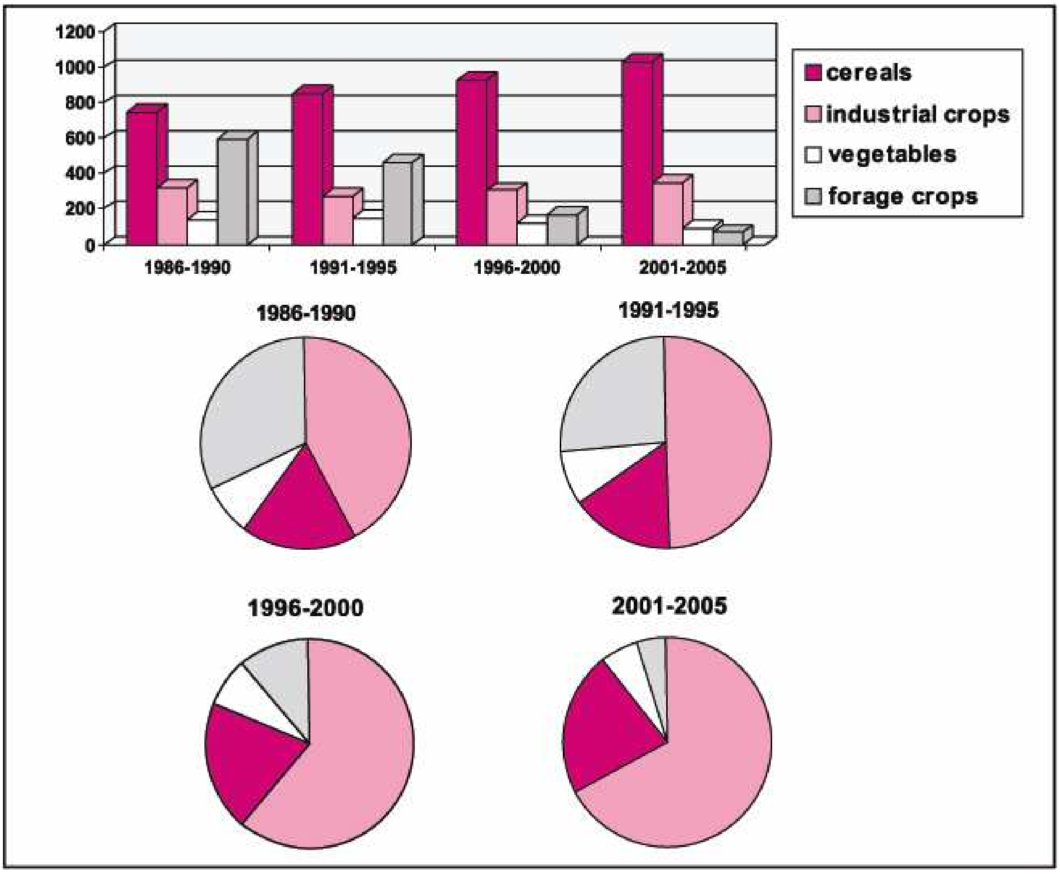
5.2.2. Characteristic of the vegetal production

The vegetal production predominates in Moldavian agriculture (according to the National Bureau of Statistics in 2007 the share of vegetal and animal productions in the total volume of agricultural production accounted for 58 % and 42%, respectively).

The domination of market mechanisms in agriculture leaded to the increase in cultivation of economically profitable crops. This is not always the way to a sustainable agriculture production, in line with environmental and soil conservation requirements.

During the last 20 years, the area of cereals (particularly wheat and corn) has increased considerably, while the areas cultivated with forage crops dropped (see **graph 6**).

Graph 6: Dynamics of the crop structure in the Republic of Moldova, 1986–2005 (,000 ha)



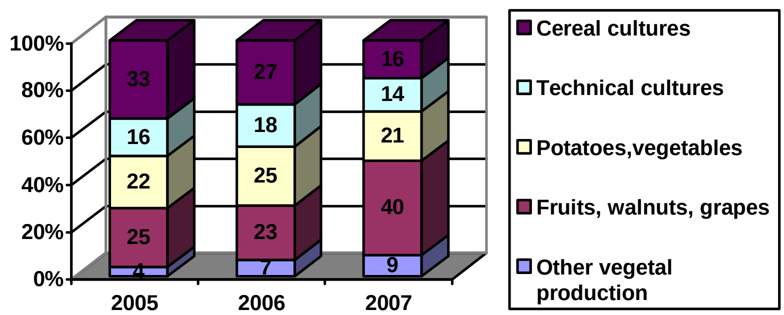
Source: *Ministry of Ecology and Natural Resources, Academy of Sciences of Moldova, Institute of Ecology and Geography, 2006.*

The exaggerated raise of corn areas leaded to non-compensated loss of organic matter from soil with the harvest and/or through erosion, especially on slopes. For Moldavian agriculture is typical that 81 % of agriculture arable land is situated on slope. Slopes steeper than 5 degrees – the most risky for agricultural use – occur in 19, 2 % of the Republic territory, predominantly in the central zone (30, 7 %), less in south and north (20, 1 %; 17, 1 %) and small area (6, 7 %) in south – east zone (Ministry of Agriculture and Food Industry of the Republic of Moldova, Research Institute of Soil Science and Agro chemistry "N. Dimo", 2001).

Another (environmentally) negative aspect is the sharp increase of sunflower plantations: the share of this crop in sown areas raised from 7.2% in 1986–1990 to 17.7% in 2001–2005. This does not allow the normal crop rotations to be applied.

Due to the fact that in 2007 there was a serious drought in Moldova, there were some changes in the structure of the vegetable production. Fruits, walnuts and grapes have a share of 40%, potatoes and vegetables – 21%, technical crops – 14%, while cereals are 16%, and 9% to other products (see **graph 7**).

Graph 7: The structure of vegetal products, %



***Source**: National Bureau of Statistics*

The cereals sector has a vital importance for the country. The main crops cultivated in Moldova include wheat, barley, corns, etc. The land area under cereals in 2007 totaled 917.6 thousand ha, corn for grains – 459.3 thousand ha. The 2007 harvest represented 2290.2 thousand tons of cereals, including 691.4 thousand tons of wheat, 1322.2 thousand tons of corn for grains. The annual domestic demand is around 600 thousand tons; the surplus of cereals is exported (Statistical Yearbook of the Republic of

Moldova, 2007).The main markets are in Ukraine, Switzerland, Porto Rico, Romania, etc.

The main **technical cultures** in Moldova are sugar beet**,** sun-flower, soy and rape. Within the national economy of the Republic of Moldova the sugar industry has specific social impact and is assigned strategic importance. This sector includes ten of thousands of employees and specialists. The wastes generated by this sub-sector are used within zootechny and spirits production. The country's annual export potential is around 50 – 60 thousand tons.

The overall volume of sun-flower, soy and rape in 2006 totaled 408 thousand tons, 88.4 thousand tons, and 7 thousand tons, respectively. These plants are the main oleaginous plants in Moldova. Over 2007 Moldova exported around 63 thousand tons of oil. The Moldovan vegetal oil is mainly traded in Romania, Poland, Belarus, Serbia and Montenegro, Kazakhstan, etc.

The share of field **vegetables** in total agricultural production accounts for around 6%. The mostly cultivated vegetables include tomatoes, cabbage, cucumbers, carrots, onion, sweet peppers, eggplants, marrows, garlic, beet, etc. The annual harvest totals, on an average, around 370 thousand tons, including: tomatoes – 26.5%; cabbage and dry onion – by 14.7%; pumpkins and marrows – 12.5%; carrots and sweet peppers – by 5.5%; eggplants – 2%; and other vegetables – 18.6%. Within the total volume of vegetables, 4.7% of vegetables are exported as fresh vegetables, 8% are used as raw material within the processing industry, and 87.3% are traded in fresh condition in the domestic market (Statistical Yearbook of the Republic of Moldova, 2007).Vegetables are exported into 23 countries of the world. Potatoes and gourds and melons are cultivated exclusively for domestic consumption; the annual harvest amount to around 340 thousand tons and 75 thousand tons, respectively.

Fruit-growing represents one of the main strategic branches of the national economy, accounting for around 40% of the agricultural production value. The area under fruit plantations in 2007 totaled 111.0 thousand ha, including: Orchards – 104 thousand ha or 96% of total area (seedy species– 67.5 thousand ha or 61.8% of total orchard area and stone-fruit species - 36.9 thousand ha or 33.8%); Walnut plantations –

5, 3 thousand ha of 3.7% of total area; Plantations under fruit-bushes – 0.9 thousand ha or 0.8% of total area. The annual average of the production volume in 2001 – 2006 totaled 401 thousand tons of fruits, including seedy species – 309 thousand tons, of which: apples – 301,5 thousand tons; pears – 6 thousand tons; quinces – 1,5 thousand tons; and stone-fruit species – 90,2 thousand tons, including: plumps – 51 thousand tons; cherries – 13,5 thousand tons; sweet cherries – 7,3 thousand tons; apricots – 5,4 thousand tons; and peaches – 13 thousand tons (Statistical Yearbook of the Republic of Moldova, 2007). Out of the total volume of fruits, 24, 7% are exported in fresh condition; 44% are used as raw materials for the processing industry; and 31, 3% are traded in fresh condition in the domestic market. Fruits are exported into 33 countries of the world.

Wine industry represents an essential branch of the Moldovan economy. Approximately 15% of the national annual budget is formed of incomes generated by **viticulture**. The Republic of Moldova is included in the world listing of first 10 countries producing and exporting wine and grapes. The total area of wine-producing plantations is 156,000 ha of vineyards, including 119,000 ha of yielding plantations. Over 95% are under private ownership. The annual vintage is 400 – 500 thousand tons of grapes (Statistical Yearbook of the Republic of Moldova, 2007). There are four wine-growing regions in the country: the Southern region (the most important region - is favorable for sweet and semi-sweet wines), the South-Eastern region, the Central region and the North region. Moldova produces annually 300 – 350 million bottles of wine, 20 million bottles of sparkling wine and 400 thousand dal of divins. Around 10% of produced wine is consumed by the domestic market and 90% is exported.

Despite all the difficulties of transition to a market economy and the transformation of agriculture (land privatization, transition from large collective enterprises to private entrepreneurship) grain production has remained a stable and key sector of agriculture.

Restraints on sustainable development in the agricultural sector have political, juridical, economic, managerial, informational, and educational dimensions. These include the low productivity of agricultural works; agricultural technologies that do not correspond to ecological requirements; insufficient support for reform; maintenance of administrative procedures and monopolistic elements unfavorable to competitiveness on the domestic and international markets; lack of adequate information technology; formal demonopolization and incomplete privatisation of fixed capital with no agricultural equipment and no service regulations; absence of an adequate crediting system (i.e., high cost of credits) and the lack of risk insurance in agricultural entrepreneurship; lack of knowledge, aptitude, and experience in modern management; insufficient opportunity for employment outside of agriculture and unemployment; and the demographic ageing and feminization of the population in rural areas, having unfavorable economic and social consequences.

5.3. Analysis of Energy Sector of the Republic of Moldova

The energy sector of the Republic of Moldova was created in the period 1950-1980 in the conditions of the centralized economy. From the technical point of view, in this period the sector evolved in the sense of the integrated power increase of the installations and industrial units of energy productions and the practice of low prices for the fuel consumed and energy produced, maintaining this situation artificially through huge Governmental subsidies and grants. The main feature of the energy sector created in that period was a high degree of centralization (UNIDO, 2001).

Upon Moldova's independence in 1991, the massive Soviet energy subsidies came to end. An extremely complicated situation occurred and still continues till nowadays in the national energy sector, characterized by the following significant factors: an advanced moral and physical wear-out of the installations and equipment, a low quality of the performed services and the energetic efficiency diminution, a high energetic intensity, 3-4 times higher than the respective indices in the industrially developed countries, the dependence on the import of the primary energetic resources, a limited number of fuel and electricity providers, the low level of electric generating capacities, the low capacity of the electric connection lines on the West direction (only 3 lines of 110kV), the unfavorable structure of the electric transport network from the point of view of the energetic security, the tendency of continuous mutual debts increase, the financial blocking of the energetic enterprises caused by huge debit and credit debts, the double increase of energy and fuel losses during the last years, the lack of investments for the energy sector rehabilitation and development (The World Bank, 2006).

The majority of the Moldavian population lives in rural communities, where living conditions are especially difficult in the cold winter months. Traditionally, coal and wood was used as a heating fuel in rural areas. After the collapse of the Soviet Union the price of fuels, including coal, increased dramatically resulting in collapse in coal consumption. Coal supplies to fuel heating systems in public buildings, especially in rural communities, were severely cutback often resulting in the closure of public buildings in the winter period as building and district heating plants stopped operating except in the biggest cities. By now the electricity supply in the rural areas don't exceed 10 of 24 hours (European Bank for Reconstruction and Development, 2002).

To mitigate the escalating energy crisis, in the late 1990s Moldova embarked on an ambitious set of energy sector reforms. The objective of these reforms was the full commercialization of energy supply, accompanied by appropriate social policies implemented through fiscal instruments to protect the most vulnerable groups (the so-called nominal compensation scheme). The main elements of the reform included: (1) the development of a new, market-oriented legal framework; (2) restructuring and corporatization of the industry whereby the country's vertically integrated electricity monopoly was unbundled; (3) privatization of three out of five electricity distribution companies covering about 70% of the market; (4) divestiture of state shared in the gas industry with the majority share in the country's monopoly gas supplier sold to Russia's Gazprom in exchange for a portion of debt; and, (5) adjustment to the level and structure of tariffs where tariffs for all consumers where increased and equalized.

The energy of the Republic of Moldova is substantially different from that of other states. Moldova is almost totally dependent on the imports of fossil fuels from Russian Federation, Ukraine and Romania. During the last decade, only 3-5% of the consumed energy was covered from internal sources. In 2005 the imports of energy reached more than 15 percent of GDP (The World Bank, 2006). The country imports both primary energy resources (natural gas, petroleum products and coal) and electricity. Nearly half of the energy imports is natural gas, about 25% are liquid fuels, and the rest is represented by coal and electricity (Institute of Ecology and Geography, 2005).

Most energy resources (70%) are spent for electricity and heat production. The main users of these types of energy are transport (about 15 %) industry (7%) and agriculture (3 %). Data on the production and use of the main energy resources are given in **table 7**.

Table 7: Elements of the energy balance of the Republic of Moldova in 1997-2006

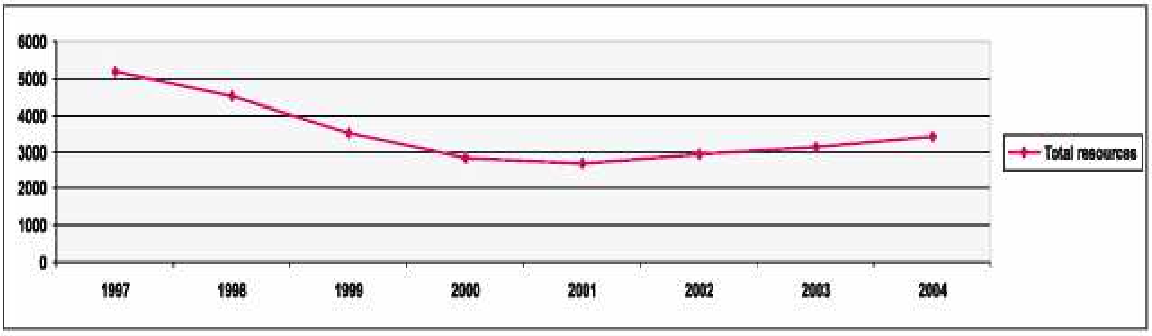
	1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Electricity production, million kWh	1450	1246	1134	904	1263	1179	1046	1022	1229	1167
Electricity consumption, million kWh	3767	3211	2566	2244	2206	2449	2527	2634	2921	3369
Heat production, thou.Gcal	6590	6120	4647	3057	3298	3217	3347	3147	3591	2637
Heat consumption, thou. Gcal	5552	5173	3899	2673	2809	2699	2799	2686	3084	2033

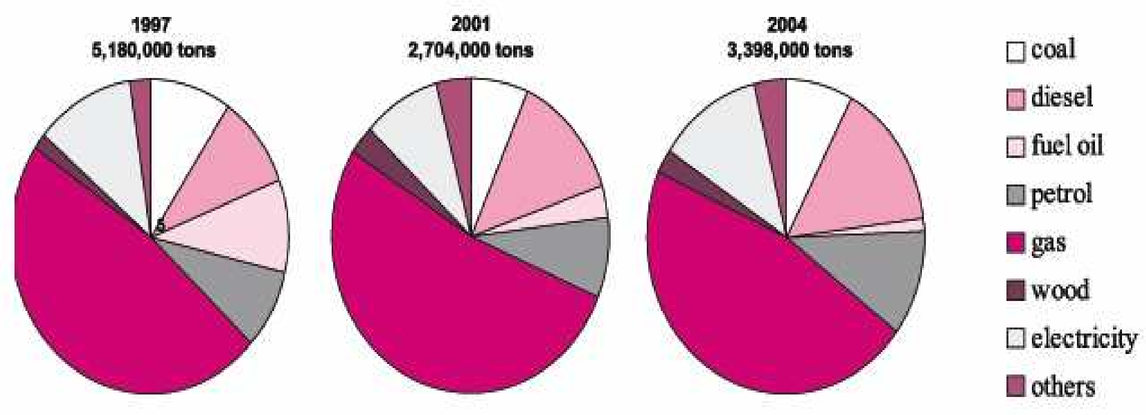
Source: *Ministry of Ecology and Naturel Resources of the Republic of Moldova, Institute of Ecology and Geography, 2007.*

The energy prices are listed in the ANNEX 3.

The energy is "the blood of economy" and energy consumption is, normally, well correlated to the state of economy. The structural reforms of the 1990s resulted in a substantial reduction in the country's industrial output, which in turn resulted in reduced energy consumption. Between 1997-2006, the use of energy resources contracted by 42%, with fuel oil (- 95%), coal (- 44%) and natural gas (- 39%) dropping the most. The only energy resource that rose during this period of time was liquified gas (+ 100%). The share of heavy fuel and coal in total energy consumption reduced drastically, due to switching most power and heat generation units to natural gas; in the same time, the share of diesel increased from 9,7% in 1997 to 12% in 2006, the liquified gas, from 1,0% to 2,9%, respectively. The importance of fire wood in the structure of energy consumption remained very small despite some growth during this period, reflecting a more active use of this local resource when the cost of fossil fuel from import went up (see **graph 8**). Starting with the late 1990s, the consumption of primary energy resources and electricity per capita entered an upward trend.

Graph 8: Dynamics and structure of energy resources consumption in the Republic of Moldova (Ktce)





Source: *Ministry of Ecology and Natural Resources, Academy of Sciences of Moldova, Institute of Ecology and Geography, 2006.*

According to the Institute of Ecology and Geography the most important national energy generation units nowadays are: two electrical and heat generation stations (EHS) in the capital city Chisinau EHS-1 and EHS-2, the EHS "Nord" in Balti, the EHS in Dnestrovsc and two hydropower stations on Nistru and Prut rivers. It must be noted that by far the largest electricity producer in the country is the Dnestrovsc station (85% of the total production). The EHS in Chisinau and Balti use the principle of electricity and heat cogeneration. They operate, on average, at 54% of their design capacity. Natural gas is the main fuel used for power generation. The specific consumption of fuel in power generation at EHS-1 and EHS-2 was increasing during the last years, indicating lower efficiency, due to the depreciation of equipment which can not be replaced because of the poor financial status of both entities. EHS-Nord had a better management and demonstrated higher efficiency in power and heat generation. The total capacity for heat generation is about 1800 Gcal. During the last years, the production of electricity at those three units has stagnated, due to financial difficulties. The cities of Chisinau and Balti have centralized heating systems. Other cities and towns rely on district boiler houses.

The entire country is covered by the energy distribution network. The number of consumers not connected to the public energy grid is insignificant. According to Key World Energy Statistics, IEA 2004 the electricity consumption per capita in Moldova is 941 kWh. It is a very small number in comparison with other European countries. For example, the electricity consumption per capita in Slovakia is 5 048 kWh, in Czech Republic is 5 886 kWh, in Denmark 6 500 kWh, in Germany 6 742 kWh, in France 7 366, in Belgium 8 315 kWh. This indicates a relative “energy poverty” of Moldova and the demand potential if the country is to achieve its objective of sustainable economic growth and poverty elimination. This also indicates that the most vulnerable categories of consumers may not have much capacity to reduce their demand further in response to the raising energy prices, which underscores the importance of well targeted safety net.

5.4. Valuation of potential of existing renewable energy sources in Moldova

The diminution of energy dependence represents a key goal of energy security and to achieve this goal a diversification of import resources has to be ensured. An important contribution to the increase of energy security of the Republic could be brought about by the exploitation of its own energy resources. For instance, a greater utilization of Renewable Energy Sources (RES) like wind, solar energy, river hydraulic sources and the use of biomass are important. In addition, greater implementation of the use of energy efficiency measures throughout all sectors of the economy is necessary.

5.4.1. Wind energy resources

There is undeveloped potential for use of wind-generated power. Presently only several experimental wind power installations are in operation in Moldova, these are used to generate electric power in autonomous systems. At the actual level of development, the commercial wind energy conversion technologies, the locations that assure an average yearly speed at the wind turbine axe altitude of 7 m/s and more with the specific wind energy higher than 350 W/m2 are considered favorable (TODOS, 2002). On these criteria it may be concluded that the Republic of Moldova has quite extended zones with a favorable for energetic exploitation wind potential, meteorologically, the most appropriate lands for location of the wind power plants are the combs and the slopes of the hills. These lands, usually arid, with a reduced fruitfulness, are less favorable for the agriculture. The price of these lands will be minimal, and their restoration for utilization will not need additional expenses.

Areas with high potential wind energy are as follows: in the north-east of the country, separate areas on the Podolsk Hills in the middle reaches of the Dniester river near the border with Ukraine; in the south-east, separate areas near the Dniester estuary; in the west, separate areas in the Carpathians piedmonts near the border with Romania (Wind Atlas of Moldova) (see ANNEX 2, map 2).

Accorging to EBRD, 2004 about 10 % of the country may be used for the wind power development. Therefore should be set the total potential wind power capacity at 1.000 MW, so the technical wind energy resource potential of Moldova could be rate as good. Specific barrier to the implementation of wind projects in Moldova is misconception that available wind potential is poor.

5.4.2. Solar energy resources

The Republic of Moldova has huge reserves of solar energy. The solar irradiation has a real duration 50 – 55 % and varies between 2060 hours in the North and 2330 hours in the South. The considerable part of the sun shine hours are in the months of

April – September and makes up 1500 – 1650 hours (TODOS, 2002). The measurements of solar radiation are carried out in Moldova only in one point – a capital of the country Chisinau. The data on monthly and annual of solar radiation incidence for this point that were averaged for the observing period of many years are presented in **table 8.**

Table 8: Monthly and annual total solar radiation incident on horizontal surface, MJ/m2

Name of place	I	II	III	IY	Y	YI	YII	YII	IX	X	XI	XII	Yearly
Chisinau	126	166	303	460	607	692	685	598	440	281	117	92	4567

***Source**: European Bank for Reconstruction and Development, 2002*

It is reasonable to use solar energy both in rural and urban locations to heat water during hot period of the year. The main barrier for development of using solar energy is an economic one. The application of small solar plants of different purposes is eliminated by the practical absence of solvent demand.

5.4.3. Hydropower resources

The kinetic water energy is relatively poorly used in Moldova: there is only one 48 MW HEP on the Nistru River, and another one of 16 MW HEP-Costesti on the river Prut. Hydropower potential is estimated at 2,100 GWh/yr including that of large, medium and small rivers. However, only 150 to 300 GWh has been generated in the last years (The World Bank, 2006). At present a special interest is paid to small rivers. Unlike large HEPs, the smaller ones on the small rivers are not of a great interest for large companies; however these may be of great use for small farms. The HEPs with a capacity of 5 MW do not damage the environment as these are complementary to the traditional systems. In many cases the small rivers may provide an essential energy supply to the agriculture (small irrigation) and to the small-scale industry (of canned goods, wine, sugar etc.); at the same time this is an advantage for the public electric networks, especially in the rush-hours. Unlike large HEPs, that require tanks for water accumulation, complex control systems, a great volume of organizational work and maintenance, the small HEPs are easier to handle and have the payback period of one year at the most (see ANNEX 2, map 3).

5.4.4. Geothermal energy resources

In the Southern part of our country there are resources of geothermal energy with a temperature of 40-460 oC (Ministry of Ecology, Constrictions and Territorial Development, UNDP Moldova, 2002), which can be used in the systems of heating for households in the near localities, but there is poor knowledge of thermal water resources and no data to be used to compute the feasibility of such resources.

5.4.5. Bioenergy resources

The notion of the biomass signifies both the biomass proceeded from the process of the agricultural plants growing and from the forestry, and that in the shape of organic residues and wastes. Implementation and growth in use of biomass boilers instead coal heating systems would contribute to environment protection.

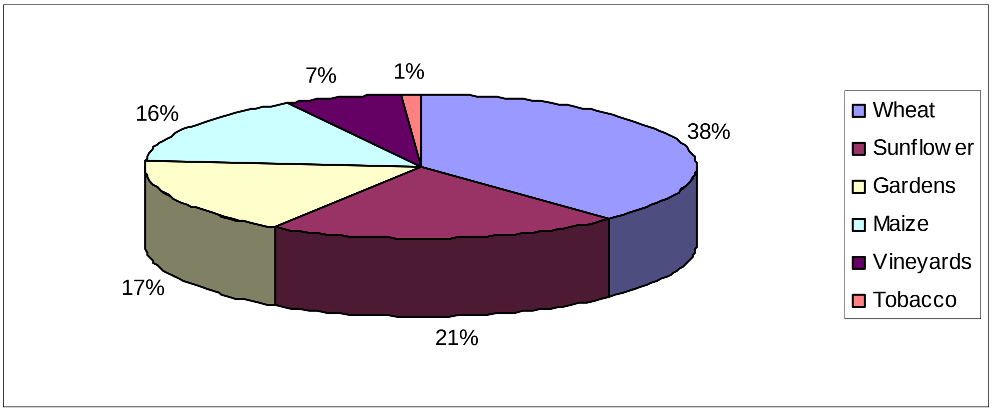
In accordance with the estimations of the specialists of the Ministry of Agriculture and Processing Industry, the State Agricultural University, the Technical University of Moldova, the Institute of Energy of the Academy of Science of Moldova and the Department of Statistical and Sociology, the energy potential of the biomass is impressive and varies between 650-900 thousands t.c.e. yearly.

5.4.5.1. Waste biomass

While not heavily industrialized, the Republic of Moldova is an agricultural country facing, the problem of agricultural wastes, especially the cereal one that are commonly burned on the field. Storage, preservation and use of agricultural wastes are still matters of discussion, analysis and planning, or even projects without any adequate practical solution. Primary and unprocessed agricultural arable crop wastes can be one of the most suitable, the easiest available and utilizable source of renewable energy, used for example for thermal energy production in Moldova, initially for use in small scale systems (50-500KWth).

The most important sources of agricultural provenience biomass in Moldova are obtained from the **pruning of the orchards and vineyards**, and also as vegetable residues in the agricultural sector: **wheat and barley straw, maize stalks and cobs, sun flower and tobacco stalks** and others. The share of the main sources of agriculture waste biomass is shown on the **graph 9**. The distribution of this biomass depends on the country regions (see ANNEX 2, map 3).

Graf 9: The share of agriculture waste biomass in Moldova



Source: *TODOS and col., 2002*

On the **graph 9** you can see that the wheat residues are predominant source of biomass, and there is a big distribution percentage of sunflower, maize residues and waste from the gardens.

Below there is a **table 9** that describes the availability of agricultural waste biomass in Moldova (the quantity of used and unused agricultural biomass in millions of tons).

Table 9: Overall estimated biomass availability in Moldova

Source	**Used**	**Unused**	**Total**
Oilseeds*650.000 ha	0.30m tons	0.20m tons	0.50m tons
Grains 600.000 ha	0.10m tons	**1m tons**	1.10m tons
Orchards / vineyards	0.40m tons	0.30m tons	0.70m tons

**The oilseeds figure understates the much higher potential availability once effective collection systems are in place*

Source: *The World Bank, 2006*

The used biomass is mostly used for animal feeding or for some industrial purposes, but not for energy production.

The data of the **table 9** proves that the country really has a great potential to use agricultural residues for energy purposes. But due to the lack of required equipment for biomass processing and mainly of lack of information on possibilities of biomass utilization and conversion into energy, this large amount of biomass is not purposely used up to the moment. For example, the most of unused straw biomass (70%) is burned on the fields for nothing, causing emission of CO2, instead of producing a fair amount of energy in a form of heat, electricity, steam or fuel.

Forest biomass

State Forestry Agency Moldsilva yearly delivers to the national economy 250-350 thousands m3 of fire wood, so as 60-70% of the rural population buys and use as fuel for heating the houses. Forests are an important stabilizing factor for the environment. In my opinion due to so little density of forests in the country, Moldavian forests should be managed well and the forest area should be increased, so it is very important to protect forest recourses from cutting, especially form illegal cutting for firewood. But the same time wood residues from forests, parks, streets and etc., represent a good alternative source of energy.

5.4.5.2. Agriculture energy crops – cultivation of sorghum and rape

The Republic of Moldova has well enough natural conditions for rape and sorghum cultivation, for production of biodiesel and bioethanol at competitive costs, from rape and sorghum, respectively.

Accordingly to the information that I have collected from the interviews and meetings with representatives of different Moldavian Research institutions during my stay in Moldova, I came to the conclusion that the first preparation for **sorghum** cultivation on the territory of the Republic started in 1973 by the *Research Institute for Maize and Sorghum*. Until now, one of the priority directions of the institute activity is production of seeds and improvement of technologies of sorghum.

Moldavian *Institute for Plant Protection and Ecological Agriculture* has a Laboratory of Sorghums; where there was crossbreed Porumbeni 4 and Porumbeni 5 sorghum species. At the end of April – beginning of May 2008, the Institute is planning to cultivate sorghum in Bursceni, Rosu and Albota de Sus villages on the total area of 70 ha. Due to the lack of knowledge on bioethanol production from sorghum and lack of appropriate technologies, sorghum mostly is exported or used as feed.

Four years ago several research institutions in Moldova focused their work to join experimental production of bioethanol. The *Research Institute of Soil Sciences and Agrochemistry "N.Dimo"* grows sorghum in a small area of 1 ha and controls its impact on the soil fertility. The *National Institute for Viticulture and Vinification* produces bioethanol from sorghum juice and the *Institute of Agricultural Technics "Mecagro"* uses bioethanol as a motor machinery fuel and energy for the next sorghum harvest. In future, Mecagro is planning to buy the necessary equipment for briquetting of sorghum dry biomass residues and then use briquettes as a renewable source of energy.

This September the first harvest of sorghum is expected, and *Moldavian Institute for Food Technologies* is planning to use it like sugar substitution: and to utilize sorghum residues as a fuel in the form of briquettes.

According to the National Carbon Union, bioethanol factory in the future will be built in Moldova in city Komrat. The factory will be oriented to the export of bioethanol.

Picture 6: Plantation of sorghum

Sorghum-to-ethanol production uses the grain, like corn, but the plants themselves hold the greatest potential for biofuel production. One hectar of sorghum can provide 3-5 tons of bioethanol (3-4 times more that cereals), while the remaining dry mass can give supplementary 20-25,000 kW of electric energy or heat. Sorghum produces high yields 80 – 100 tons of green mass, is naturally drought tolerant and growing very good in the conditions of Moldova. The energetic effectiveness of bioethanol and briquette production from sorghum as energy carriers is 1:12, 2 (that’s mean that 6,3 mil. kcal that were used for growing of 1 ha of sorghum provides 23,6 mil. kcal in form of bioethanol and 54,6 mil. kcal in form of briquettes). Besides, the sorghum has an exceptional capacity of absorbing carbon dioxide: 40-50 t/ha/year (as compared to broadleaved forests, 16 t/ha/year, or cereals, 3-10 t/ha/year). Also, the amount of carbon accumulated in sorghum roots contributes to the positive balance of humus in soil (1.5-2 t/ha/year).

Rape for the first time was cultivated in Moldova in the middle of the XIX century (1840-1850). Nowadays, it is widely used in production of vegetable oil and as a fodder for animals. In comparison with the cost of sunflower cultivation, the cost of rape cultivation is 36 - 40 % cheaper; the seed yield is 50 % higher, income from unit of the area is 30 - 40 % higher; and there is a high and guaranteed potential for export to European Union countries.

Growing of rape effectively prevents soil erosion and besides enriches the soil with organic fertilizers and improves its mechanical structure. It is very good and important to include rape and sorghum to the crop rotation systems.

However, because of its weak tolerance to drought and frost, rape is not widely distributed in Moldova yet, and its yield is rather low (7 thousand tons in 2007). In this connection research institutes which are responsible for cultivation of this crop have to find a new species and rape hybrids with high drought and frost resistance and with higher content of oil in the seeds.

Last years rape oil is in great demand in the markets of mineral oil, being a good vegetative substitute of solar oil, gasoline and gas. One hectare of rape can provide 1,0-1,2 tons of biodiesel.

In 2006 the first Rape Seed Processing Factory Ltd. "Biocompani-Rapes" was put into operation in the North of Moldova in city Lipcan. The factory produces rape oil and biofuel that are exported.

In the beginning of 2007 Russian company WJ has declared a big interest to start manufacture of biodiesel together with Moldavan joint-stock company Floarea Soarelui in Moldova. And in 2008 in Moldova an American company FuelMarkers is planning to build a factory for biodiesel production too.

Picture 7: Rape plantation for biodiesel production

According to the Strategy of renewable energy sources development, the implementation of technologies for cultivation and processing of plants for biofuel could provide some 80,000 tons bioethanol and 110,000 tons biodiesel, which is about 10% of the fuel used in country. This would need the cultivation of 163,000 ha with sorghum and rape (approximately 10% of the sown area in 2005).

5.5. Starting of field-tests of new energy plants growing in Moldova

Moldova does not have any experience in cultivation of energy plants; and here were no analogical experiments in that country. Energy plants are the plants with high energy yield; its energy yield is much higher then energy yield of waste biomass. The cultivation of energy plants for energy purposes could be a great solution of energy problem of agricultural Moldova.

The experiment started in the middle of April 2007, when the first energy plants were planted on the experimental fields of the Moldavian State Agricultural University in Chisinau within the framework of the development project “Support Development of Study Programmes at the Agriculture University in Chisinau and Coordination of its Education System with EU Standards”.

On the first experimental field divided into five parts 10 m x 10 m there were planted the following energy grasses: *Phalaris arundinacea, Malva crispa, Rumex tianschanicus x Rumex patientia, Helianthus tuberosus, Miscanthus sinensis,*

On the second experimental field divided into four parts 13, 5 m x 11 m there were planted fast-growing energy trees: *Populus coreana, Populus nigra x Populus maximowiczii, Salix viminalis, Salix alba*.

In the middle of September 2007 the other energy grasses (*Camelina sativa, Phalaris aquatica*) were brought from the Czech Republic and planted as well on the field divided into two parts 13,5 m x 11 m near the field with energy trees (the maps of experimental fields are in the ANNEX 4).

It was decided to examine how the chosen plants would grow in the natural conditions of the Republic. From the beginning it was agreed to cultivate all these plants with the minimum economic inputs: the subsoil ploughing was done before planting and no other soil preparations, the planting was done manually and not any chemical of mechanical treatment and even irrigation has been expected.

5.5.1. Energy grasses

For the establishment of the field with energy grasses it was necessary to collect and search the information about chosen species. It was also necessary to overlook and analyze the climate and soil conditions of Moldova and its landscape tool (the valuation of Moldavian climate, soil and landscape are represented in the chapter 5.1.) On the base of collected information the energy grasses were planted on the experimental field, the recommendations to its harvesting and future cultivation in the territory of Moldova and the advantages of each plant were elaborated.

5.5.1.1. *Phalaris arundinacea*

Phalaris arundinacea- **reed canary grass** belongs to family ***Poaceae***. It is a herbaceous perennial plant growing **over 2 m** tall.

The average yield of dry-matter ranges between **4 5 - 9, 0 t.ha^{-1}**. The heating value of dry-matter of the above-ground biomass is **17,52 MJ.kg^{-1}**, the production of energy creates **140, 5 GJ.ha^{-1}.rok** (STRAŠIL, 1998).

Picture 8: *Phalaris arundinacea*

Founding the growth on the experimental field in Moldavia

Seeds were sown on the experimental field in the middle of April 2007 in the cultivated soil. Sowing was done in rows in the distances of 15 cm and 2-3 cm deep

Note: Red canary grass is not pretentious about the sowing date; it can be sown in the period of March to June, and also during August.

Recommendation for the harvest

Red canary grass grown for the energetic utilities is not harvested in the year it was sown. From the energetic and economic point of view, it is recommended a winter or spring harvest, when the dampness of dry-matter declines under 20 %, this biomass is directly compressed into briquettes or pellets, stocking or immediate burning. The 25 % loss of red canary grass biomass over the winter period is not high comparing to other crops (for example sorghum loses 37, 3 %). The losses are compensated with the decreasing dampness, because over the autumn it is necessary to dry the harvested biomass. Spring harvest is also recommended because, with the late harvest the amount of potassium, chlorine, nitrogen and sulphur in the biomass decrease.

It is possible to use ordinary agricultural machines for the harvesting (for example threshing machine or reaping machines).

Advantages of reed canary grass cultivation:

- For the implementation of basic growth of reed canary grass a very low price is needed, no or minimum utilization of herbicides or pesticides (usually diseases neither pest make no harm to Red canary grass) and other low direct expenses;
- Non-overlooked advantage is that the red canary grass can be cultivated almost on all soil-climatic conditions. Red canary grass gets on well on most of the soil, it is well adaptable to soil reaction in range from 4, 0 to 7, 5 pH. After rooting it is resistant to longer droughts. Black frost neither late spring doesn’t harm it. It can also stand shading or short-term floods;

- Another advantage of growing red canary grass is its versatile utility. Besides its utilizations for the direct burning or the production of electricity it is possible to use it’s biomass in green state as fodder (fresh forage, hay, silage) eventually for the production of biogas. The growth can also be used for the seed production.

Suggestions and recommendation for the future cultivation of red canary grass in Moldova

According to my opinion, Red canary grass could be cultivated on every territory of Moldavian Republic, as in lowlands so in higher locations. To reach high yield biomass, it requires adequate moisture and also nutrients, mainly nitrogen (fertile soil requires only N 50 to 80 kg.ha-1 doses, it is possible to side-dress annually preferably in spring before the vegetative season. I would recommend cultivating Red canary grass near stream surroundings.

In case of cultivating Red canary grass on agricultural soil, it can be well included into the crop rotation since it is not demanding to preceding crop. The best preceding crops are the leguminous-cereal mixture and cereals.

5.5.1.2. *Malva crispa*

Malva crispa - ***Malva*** belongs to family ***Malvaceae***. It is a herbaceous perennial plant growing up to 1,5 – 2 m tall. The average yield of dry matter is **10-15 t.ha^{-1}**.

Heating value of dry matter of above-growing biomass is **17, 58 MJ.kg^{-1}** and the energy yield is **235, 58 GJ.ha^{-1}.rok** (PETŘÍKOVÁ, 1997).

Picture 9: *Malva crispa*

Founding the growth on the experimental field in Moldavia

Seed of Malva were sown on the experimental field in the middle of April 2007. Sowing was done in rows in the distances of 25 cm between rows and 1-2 cm in depth.

Recommendation for the harvest

Malva dries up in September, which is the best time to harvest it for energetic utilities. During the harvest part of the seeds emerge forming a fully joint (that is why this annual crop often included amongst the constant). For the energetic purposes Malva is harvested once a year with the help of ordinary machines.

Advantage of growing Malta cultivation:

- This crop grows well even under unfavourable climatic conditions and is not so demanding to soil fertility;
- The importance of growing Malva consists in its very quick emergence in spring and overgrowing. Thereby forming a fast rank of growth, this acts like a biological weed agent and as a soil protection from erosion;
- Except its use as an energetic crop (for burning and production of biogas), Malva is also used for green fodder, as a medical or decorative.

Suggestions and recommendation for the future cultivation of Malva in Moldova

According to my opinion Malva can be well grown on the flooded lands, where it is easy to liquidate weeds. But during big droughts the plant can badly fight weeds; therefore it is recommended to treat the growth mechanically.

It is also good to make use of the plants capabilities of soil protection from erosion and to establish growth on endangered soil with erosion, for example on slopes and bottom of hills.

A best result reaches Malva on fertile soil with an adequate content of lime, balanced amount of substances and enough moisture. That's why I would recommend fertilizing the soil with manure etc. But it is necessary to remember, that to a high amount of N in soil the plant tends to nitrogen fixation.

5.5.1.3. *Rumex tianschanicus x Rumex patientia*

Rumex tianschanicus x Rumex patientia also called as **Rumex OK2** or sorrel of Uteush belongs to the family ***Polygonaceae***. It is a herbaceous perennial plant that can reach up to **2,2 - 2,6 m** in height. The average yield of dry matter is **14-16 t.ha^{-1}**. The duration of plantation is 15 – 20 years.

Heating value of dry matter of above-growing biomass is **18, 5 MJ.kg^{-1}** and the energy yield is **278 GJ.ha^{-1}.rok** (USŤAK, USŤAKOVÁ, 2004).

Picture 10: Rumex OK2

Founding the growth on the experimental field in Moldavia

The plant seeds were sown to the ploughed land of experimental field in the middle of April 2007. Parameters for sowing were as follows: depth - 1.5-2 cm, width of rows –20 cm and distance between plants - 10 cm.

Note: Rumex OK2 is a very adaptable plant with regard to the sowing period: it can be sown from April to July with the same results, the only condition being that the soil is sufficiently wet (e.g. after heavy rainfall).

Recommendations to harvesting:

From bioenergy point of view is very important, that this plant finishes the vegetation fast and dries. So its' dry biomass can be harvested already in July, when the moisture of biomass is less then 20 %.

For energy purpose Rumex OK2 is harvested ones a year and common agricultural machinery is used.

Advantages of Rumex OK2 cultivation:

- It has a very high adaptability to the soil and site agro-ecological conditions. It has no special requirements for soil fertility or nutrient content. It doesn't need any chemical treatment against pests, because no diseases have been determined. It is high resistant to freezing;
- The Rumex OK2 is easily reproduced with seeds, unlike many other highly productive energetic crops (for example Miscanthus);
- The great advantage of Rumex OK2 in comparison with other energetic crops is early ripening - as soon as the middle of summer it is possible to harvest the hybrid sorrel as dry energetic biomass;
- The plant has a strong stem that is very resistant to rain and wind that is why the biomass losses are very low;
- In addition to the use of Rumex OK2 as a very potential energetic crop, there are excellent possibilities for its use as a food or fodder crop, because it has a high content of valuable essential nutrients and vitamins. Seeds can be successfully used as a hard fodder or as seeds for sowing.

Suggestions and recommendation for the future cultivation of Rumex OK2 in Moldova

In my opinion, the hybrid sorrel can grow well on non-agricultural land in Moldova and can give a high biomass yields. I don't recommend its planting near river or lake banks, because of its' poor tolerance to waterlogging. As very acid soils (<5.5 pH) can have a negative impact on a normal grow of the plant. I suppose that it can be very useful to cultivate Rumex OK2 on the lands affected by erosion, because of its' good ability to erosion protection.

For the higher biomass yield some minimal ration of fertilizer can be applied and extended only over the first year (for example 60-90 kg.ha-1 of NPK or 40-80 t.ha-1 of some organic manure).

For the successful establishment of Rumex OK2 cultivation it is necessary to prepare the soil very carefully. The main problem is weeds. When the sorrel begins to grow, it is necessary to loosen the soil by weeding (usually 2-3 times during the first year). In the later stages of development sorrel naturally inhibits the growth of most types of weed, making chemical treatments unnecessary.

Due to 1, 5 – 2 m deep rooting, the plant is using well an underground water and can survive dry shells. But heavy drought can cause the weakness of the plant, its' can be badly attacked by pests, disease and weeds, in this case chemical protection is necessary.

5.5.1.4. *Helianthus tuberosus*

Helianthus tuberosus – **topinambur** belongs to family ***Asteraceae*.** It is a herbaceous perennial plant growing to **1, 5 - 3 m** tall.

Average yield of green matter can vary from **5** to **48 t.ha^{-1}**, the tubers' yield varies from **4,4** to **76,5 t.ha^{-1}.** Average heating value of dry matter is **18,032 MJ.kg^{-1}** and average heating value of tubers is **16, 344 MJ.kg^{-1}** (STRAŠIL, 2002)

Picture 11: *Helianthus tuberosus*

Founding the growth on the experimental field in Moldavia

Topinambur was propagated by tubers. Whole tubers or pieces about 50 g were covered to a depth of 10 cm and planted 40 cm apart in rows which are 70 cm apart. Topinambur was planted on the experimental field in the middle of May 2007.

Note: Loosening of soil is recommended before planting. Topinambur should be planted as early as possible in the spring when the soil can be satisfactorily worked. Late planting usually reduces tuber yields and size seriously. Planting was done late in Chisinau due to the late delivery of tubers. Tubers or its pieces larger than 50 g do not increase the yield, though those smaller will decrease it. Deeper planting may delay emergence, weaken the sprouts, and cause the tubers to develop deeper, making harvest more difficult.

Recommendation for the harvest

The tubers can be harvested in autumn or spring; technological spring harvest is more suitable. The tubers' harvest can be done by potato-harvesting machinery with predominantly hand – digging.

The harvest of stems for energetic purposes is recommended to do in spring before tubers' harvesting. Stems can be harvested by corn cutter.

Note: Harvested tubers - good, sound, disease free can be successfully kept several months in cold storage at a high humidity (100 %) and a temperature of 2°C before being processed into bioethanol.

Advantages of topinambur cultivation:

- Topinambur is a very easily grown plant, it can succeeds in most soils, along roads and the edges of forests, in any odd bit of ground shaded or open, can grow successful in very poor soils;
- It survives in dry regions and tolerates hot to sub-zero temperatures. The tubers are very cold-tolerant and can be safely left in the ground in the winter;

- The plant can tolerate strong winds;
- It is good weed eradicator; it makes so dense a shade that few other plants can compete;
- Dry above growing biomass is a very potential energy source with a high heating value. Beside it stems and leaves are rich in fats, protein and pectin, and make good forage and silage.
- The tubers are in great potential for bioethanol production. Ethanol yield is about **77 l.t-1** of tubers. The tubers can be also used in food industry; they content inulin, which is tolerated well by diabetics. The tubers can be also used to fatten livestock.

Suggestions and recommendation for the future cultivation of topinambur in Moldova

In my opinion topinambur can be very perspective energy source in the conditions of the Republic.

Due to high tolerance of wide range of soils, I recommend using for topinambur cultivation the soil that is unsuitable for other crops. Heavy soils produce the highest yields, but the tubers are easily damaged at harvest-time so lighter well-drained sandy loams are more preferable.

According to the Research Institute of Plant Production in Lukavci, Czech Republic the yield of dry matter responds to N fertilization. The 60 kg.ha-1 N rate increases the stems' yield up to 27%, 120 kg.ha-1 N rate up to 32, 4 % compared with the no nitrogen treatment. So it can be suggested to fertilize the plant with N in order to get better yield of above growing biomass.

It is necessary to remember that plants can be invasive. So in case that topinambur is included into the crop rotation is recommended to plant as a following crops spring mixed crops or feeder root-crops.

5.5.1.5. *Miscanthus sinensis*

Miscanthus sinensis – **Miscanthus** belongs to family ***Poaceae***. Is a herbaceous perennial plant growing up to **3 m** (rarely 4 m) tall.

In the second year of harvesting the average dry matter yield composes **10 t.ha^{-1}** and in the third and latest years the average yield can reach up to **15 - 25 t.ha^{-1}** of dry matter**.** The heating value of the dry plant biomass is **19, 0 MJ.kg^{-1}**. The energy yield is **268,3 GJ.ha^{-1}** (KÁRA a kol., 2005).

Picture 12: *Miscanthus sinensis*

Founding the growth on the experimental field in Moldavia

Miscanthus was propagated by rhizomes. About 10 cm long rhizomes were planted on the experimental field in the middle of May 2007; each rhizome was covered to a depth of 10 cm and planted at 1m3.

Note: The best time for rhizomes' seating is middle of April, before the rhizomes start to sprout, otherwise young shoots can be damage by manipulation. Planting was done late in Chisinau due to the late delivery of rhizomes.

Recommendations to harvesting

Harvesting can be done by mobile self-propelled corn cutter. The best harvesting period is form January till March when the plant dry matter content is the highest. Miscanthus is not harvested in a first year, but later is harvested annually.

Advantages of Miscanthus cultivation:

- Miscanthus can tolerate a variety of poor conditions, including soils of various pH, soils that are acidic, sandy, loamy, clay or slightly alkaline, it has low demand of nutrients and doesn't require a lot of water especially in the late development stages, so there is no need of additional fertilizer and irrigation; and hot summers; slight drought can be tolerated when the plantation is established;
- Miscanthus tolerates strong winds, so the plantation doesn't lodge during the winter time (for example, it is a big advantage of Miscanthus in compare with sorghum)
- The plant is very resistant against insects and diseases and doesn't need any protection during cultivation;
- Miscanthus needs a short time to obtain a full productivity of plantation;
- Perennial plantations of Miscanthus play an important role in order to soil protection and revitalization as well as for landscaping;
- Miscanthus has a great potential for heat production (by combustion or by pyrolysis). The combustion of Miscanthus bales is steadier and cleaner than wheat straw combustion, probably because of better air movement in the bales;
- Miscanthus has low ash content (2-3 %) compared with other lignocelluolosic species. Ash from miscanthus biomass combustion can be applied as field fertilizer. The miscanthus ash contains 2-3 times more minerals and 3-10 times less heavy metals comparable with tree ash;
- Besides the energy industry the raw materials of Miscanthus can be used for the paper production, for insulation and building, it may be used like ornamental plant in the houses, parks and gardens as well as livestock feeding. The flowers are useful for dyeing.

Suggestions and recommendation for the future cultivation of Miscanthus in Moldova

I suppose that Miscanthus can grow almost everywhere on the territory of Moldova. Higher precipitations and higher temperature during vegetative period increase the biomass yield. It is better to irrigate it during the heavy drought especially in the south of the republic. I don't recommend to cultivate Miscanthus near river or lake banks, because it doesn't tolerant the waterlogging. And salt soil is not very suitable.

Miscanthus grows better in warmer areas. It is important to know that the plant can freeze out during the first winter after planting. In order to keep the plantation is recommended to cover it with 100 – 150 mm of straw layer for the first winter or to seed the white mustard to inter-rows at the end of July – beginning of August at the year of plantation establishment. But comparing with sorghum, Miscanthus has smaller temperature requirements.

The plant can be included into the crop rotation system in agriculture land. It is suitable to plant it after tuber crops such as sugar –beet and potatoes, after pulses and cereals or after rape, sorghum or corn. Miscanthus grows well on non-agriculture land and on roadsides, forest edges, sides of reservoirs, in old fields following fires, in the mid to upper slopes as well.

The significant **barrier** for the large utilization of the Miscanthus in Moldova is very high cost of the plantation establishment. But considering the long duration of plantation (10 – 20 years), high biomass yield and great energy yield the plantation establishment will repay.

5.5.1.6. *Camelina sativa*

Camelina sativa - **false flax** belongs to family ***Brassicaceae***. It is a herbaceous annual plant growing up to **0, 6-1, 2 m** tall. The average yield of seeds is **0,2-1,8 t.ha^{-1}** and the average yield of dry matter is **1,1-8,3 t.ha^{-1}**.

Combined heat of dry straw biomass is **15, 2 MJ.kg^{-1}** and the energy yield is **58,2 - 98,3 GJ.ha^{-1}.rok** (JEŽKOVÁ, 2002).

Picture 13: *Camelina sativa*

Founding the growth on the experimental field in Moldavia

Seeds of winter false flax were sown on the experimental field in the middle of September 2007. Sowing was done in rows in the distances of 13 cm between the rows and 1-2 cm in depth.

Note: recommended period of sowing is the end of August, but to reach high results false flax requires early sowing. Sowing was done late in Chisinau due to the late delivery of seeds.

Recommendation for the harvest

False flax is harvested in its full fledged state with ordinary harvesting threshing-machine, without the necessity of adaptation. (Because the false flax is unpretentious to agricultural engineering, it is preferred to rape, sun-flower etc.).

Advantage of false flax cultivation:

- False flax is a very humble crop. Suits almost for all pitches, is not pretentious to substances. Is very resistant to droughts and tolerates low temperatures;
- It has short growing season (3 to 3,5 months);
- Possible to grow without pesticides, false flax is resistant to diseases and pest;
- The plant has many-sided utilities. Straw is used for burning and also for the production of brushes and brooms. Corn contains 33-44% of oil, which can be used cosmetic and manufacturing industry (colour production, paints, lubricants, oil and soups).

Suggestions and recommendation for the future cultivation of false flax in Moldova

False flax could be a very suitable variation to use for poor and endangered soil with erosion. I would not recommend growing it on heavily flooded, acid and very fertile soil.

False flax can be included in plant rotation, it gets on very well after almost all preceding crop except crops from *Brassicaceae* tribe. The best preceding crop are leguminous and leguminous-cereal mixture.

5.5.1.7. *Phalaris aquatica*

Phalaris aquatica **– Harding grass** belongs to family ***Poaceae***. It is a herbaceous perennial plant growing up to **1-1, 5 m** tall. The average yield of dry matter is **19, 8 t.ha^{-1}** (Australian Journal of Experimental Agriculture, 2006).

Combined heat of dry biomass is **18, 4 MJ kg^{-1}** (Journal of Applied Ecology, 1982).

Picture 14: *Phalaris aquatica*

The requirements to soil and climate condition, the principles of plant sowing and harvesting are very similar to *Phalaris arundinacea.*

Founding the growth on the experimental field in Moldavia

The plant seeds were sown to the cultivated land of experimental field in the middle of September 2007. The depth of sowing was 2 - 3 cm and the width of rows – 15 cm.

Note: This grass is slow to develop from seed.
The recommended periods of sowing are: from March till June or during the August. Sowing was done late in Chisinau due to the late delivery of seeds.

Recommendations to harvesting:

Harding grass that is cultivated for energy purposes is not harvested in a first year. Starting from the second year the dry biomass is yearly harvested by common agriculture machinery and the best harvesting period is in spring.

Advantages of Harding grass:

- Very resistant and drought tolerant grass. Grows on a wide range of soils, moderately shallow, moderately acidic, sedimentary soils to deep, self-mulching, alkaline clays. Tolerates wet soils, flooding and moderately saline soils;
- Very resistant against insects and diseases, doesn't need any protection during cultivation;
- Capable of aiding in the control of many serious weeds;
- Beside energy use, is widely used as forage.

Suggestions and recommendation for the future cultivation of Harding grass in Moldova

Harding grass can grow well in many areas of the Republic. It can be suitable to table-lands and slopes as well as waterlines.

It is recommended to plant Harding grass on soil affected by erosion in order to use its ability to soil conservation.

5.5.2. Energy trees *(Populous trichocarpa x Populus koreina, Populus nigra x Populus maximowiczii, Salix viminalis, Salix alba)*

As energy trees were chosen to be grown in Moldavia, they were specially improved for energetic purposes fast-growing clones of poplars (*Populous trichocarpa x Populus koreina, Populus nigra x Populus maximowiczii*) and willows (*Salix* *viminalis, Salix alba*). After five years under optimum conditions they can reach up to10 –15 m high.

The heating value of poplar wood chips (different clones) is **18, 7–19, 2 MJ.kg^{-1}**; heating value of willow wood chips (different clones) is **18, 2–19, 0 MJ.kg^{-1}** (KÁRA, 1995). The average energy yield of chosen energy trees is **140 GJ.ha^{-1}** (Kolektiv řešitelů, 2006).

Common recommendation for fast-growing trees cultivation

Preparation of planting material

The chosen clones of poplars and willows as planting material are the cuttings (18-22 cm long and 8 - 20 mm wide) cut from annual stems cuts (sprout). It is necessary to store the stem cuttings for planting in suitable storages. During the short-term storage (1-2 months) is the optimum temperatures +2 + 4 oC. For the long-term storage (5-7 months) is recommended lower temperatures 0o - 4 oC and high dampness. In the time of planting it is good to dip the cuttings into the water for one day (RILOG, 2004).

Soil preparation

Before the planting out of the cuttings it is necessary to make a deep ploughing in autumn (35 cm). For the spring preparation it is possible to use the combined skids with gates, cultivator, and rotavator. The soil must be well worked out to the depth of 20 cm, for easy planting.

Planting

Planting is done manually or with the help of mechanization (for example classical forestry two-row planter behind the tractor). Stem cuttings are planted upright almost at the surface level of soil – stem cuttings can stick out at the height of 3 cm above the soil surface, very important is the cementation of soil around the stem cuttings. Planting is necessary to be done at the beginning of spring, so that the cuttings catch up as much of moisture needed to grow and rooting. According to WEGER, KNORR, 1997 when planting into one-row it is recommended to make a 1,5 to 3 m distance between rows, cuttings are planted 0,5 m from each other (planting parameters must correspond with the width of available panting a cultivating machines).

Treatment of fast-growing trees during vegetation and fertilization

With regard to big sensibilities of young timber sprout in competition with weed, it is very important, especially in the initial stage of growth, to ensure the side cultivation with manual hoeing in an instant distance of the plant. For the mechanical treatment of the young plants during vegetation it suits to use the combined cultivator or rotated mulch-laying machine. Cultivation is done in 2nd – 3rd year after planting out. In following years cultivation is useless.

In most cases fertilizing is necessary.

Harvest of fast-growing trees

A plantation of fast-growing trees is harvested in so called very short rotation, which occurs in 3rd or 6th year. The lifetime of the plantation is generally 15–25 years; this means that, the harvest is done 4–8 times. The short rotation harvest is not recommended, because with it the total production effectivity of biomass can be reduced (RILOG, 2004).

The annual average increment in dependence to length of the rotation, clones and the location of poplars and willow is about **8 to 25 t.ha^{-1}** (**table 10**).

Note: The **table 10** shows that, in the case of poplars the annual dry-matter increment and the total yield of dry-matter would be perspective to choose the six year rotation. Besides, willow has the annual average increment higher after three year rotation. The table based on the experience of Milan ŠINKORA from Czech Republic shows that the total yield of poplars is much higher then the total yield of willows. That is why it will be very important to focus the attention on this fact and to monitor the yields of chosen trees in different period of rotation in the conditions of Moldova.

Table 10: The annual average increment of dry-matter and the total yield of poplar and willow clones in dependence on the length of rotation (t.ha-1).

	Poplar		Willow	
	Three year cycle	Six year cycle	Three year cycle	Six year cycle
Annual increment	15,6	21,2	10,1	8,9
Total yield	46,8	127,2	30,3	53,4

Source: *ŠINKORA, 2008*

Fast-growing trees are harvested in winter (December-March), when the soil is frozen and the dry-matter is high as (50 %). Current methods are used to fell timber i.e.; with the help of a power saw, in some cases hydraulic or pneumatic shear. The chopped down material can be worked out right on the plantation with the stationary or mobile crusher and chips are taken to storage halls, where it is being dried out to dampness of 20–30 %. As advantageous, though energy pretentious is the method of transporting the cut down timber from the plantation and carry out crushing after drying out and before consumption. Above mentioned methods are laborious and expensive.

Founding experimental plantations fast-growing trees in Moldavia

Planting material, brought form Czech Republic to Moldavia, was stored for a short time under correct storage conditions. Before planting, a very good soil preparation was done in spring. Stem cuttings were manually planted in the middle of April 2007. One stem cutting on 1 m 3, under annual condition and methods of cultivation and harvest.

Advantages of growing fast-growing trees species

- Very high energy yields;

- Survival of clones used for energetic purposes is very high and tree morbidity is very low, there are not known any symptoms or damage cause by abiotic or biotic factors (LANDA, 2004);
- Fast-growing trees have excellent regenerative capabilities – very active overgrowing capability after scarfing the overhead part;
- When growing fast-growing trees, the soil relaxes from chemical fertilizers and recovers the natural composition;
- Establishing the fast-growing trees plantations presents an effective non-grocery used of an agricultural land;
- Plantation of fast-growing trees has a capability of holding back water, by which it markedly reduces the ablation of most fertile layers of arable land;
- Plantation of fast-growing trees can function like a natural wind-break, which obstructs drying out of soil, wind erosion ;
- The important function of the plantation is isolation and reduction of negative activities of surfaces and object: reduction of dustiness, noisiness, formation of root shutters to protect water sources;
- Biological and landscape functions of energy plantation is very important: creation of bio-corridor and forest companies in a non-forest agricultural landscape, increasing biodiversity of agricultural landscape, shelter and food for small animals, breeding place of birds(MAFI, 2001).

Suggestions and recommendation for the future cultivation of fast-growing trees in Moldavia

Growing poplar clones. Poplar clones grow well in neutral or weak acid soil. Acid soil under the pH 5 is not suitable for this type of timber (MOTTL, ÚRADNÍČEK, 2003). Optimum locations are characterized by the sustained irrigation, which poplar needs for maximum production. That's why I would recommend establishing plantation of fast-growing poplar near the water flow. Poplar tolerates few weeks-long floods. According to MOTTL, 1998 clone *P. nigra x P. maximowiczii* grows well on a wide spectrum of locations even in piedmont areas (350 – 500 m.a.s.). It shows quick terminal growth in initial stage and thick branches in the lower part of the stem, which good for repression of weeds. Clone *P. trichocarpa x P. koreana* is more pretentious to the soil preparation and Feeding out. Poplar is very productive under good conditions. It also displays resistance against late frost.

Growing willow clones. Willow clones best grow in clayey and clayey-sandy, which can keep the moisture even in summer. According to LANDA, 2004 clone *Salix alba* prefers waterlogging locations, bottom land along the water stream, damp green fields. Clone *Salix viminalis* grows well on a wide spectrum of locations over acid slope soil, to humus and flooded land of water stream from high positions to lowlands. They don't grow well on underflooded and gley soils, it is better plant to plant white willow in this places. Clone can be used in dryer locations, because it is adaptable to agricultural soil.

5.5.3. Monitoring of the energy plants growing in Moldova

There are five monitoring were done during the year in order to monitor the growing process and measure the main grow parameters of the energy plants such as high, survival and others.

- **1st monitoring – end of April 2007**

The first monitoring was done two weeks after planting the first energy grasses and trees. The grasses which were sown by seeds in the middle of April - *Phalaris arundinacea, Malva crispa, Rumex tianschanicus x Rumex patientia* haven't intergrow. It was normal, because the grasses are developing from the seeds slow.

All clones of energy trees have already started to grow actively. The first leaves start forming from buds on the majority of planted steam cuttings; it means that the cuttings of energy trees have started to root.

Below there are represented the **photos** of fast-growing trees two weeks after planting.

- **<u>2nd monitoring – middle of May 2007</u>**

The second monitoring was done 1 month after planting, at the same period when another energy grasses - *Helianthus tuberosus, Miscanthus sinensis* were planted on the experimental field.

The energy grasses which were sown in the middle of April still haven't rise up, but it was expected, because the grasses usually needs more time to develop from the seeds.

The root system of the energy trees continued to develop. New leaves were formed.

- **<u>3rd monitoring – middle of September 2007</u>**

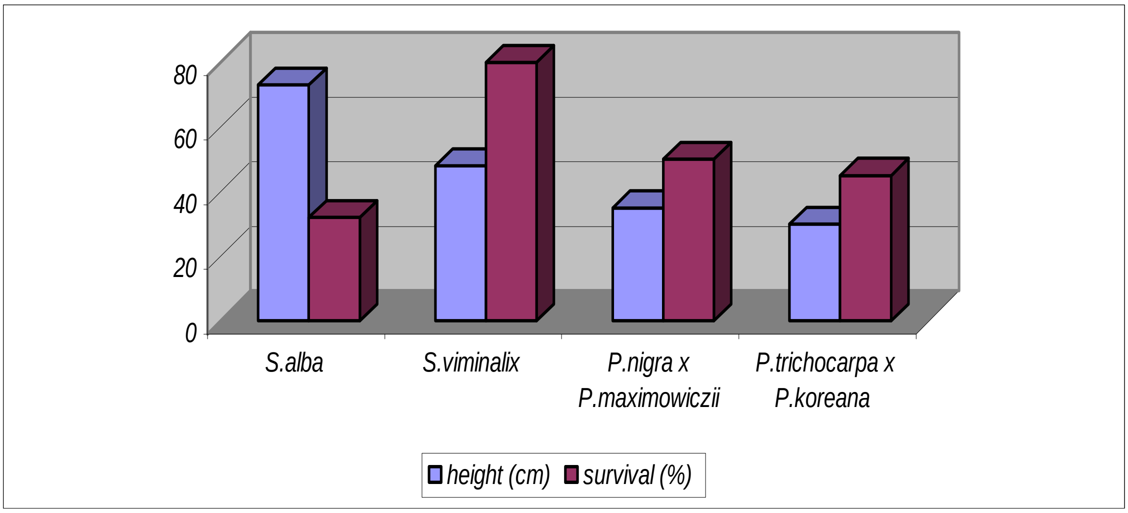
The third monitoring was done 5 months after the sowing of three first grass species and 4 months after the planting of two other grass species. The monitoring was done together with sowing of new grasses such as *Camelina sativa, Phalaris aquatica.*

The monitoring shows that all energy grasses haven't rise; and it was clear that they haven't survived and were killed probably of extremely dry summer. This year in Moldova the average precipitation was not even the half of the normal summer norm. Taking into the account that even normal average rate of summer precipitation is low, it can be concluded that the summer was really drastic. Late planting could be the reason that *Helianthus tuberosu* and *Miscanthus sinensis* could not stand the drought.

In spite of heavy drought the situation with 5 months old energetic trees was different: *Salix alba* has reached up to 73 cm in average (but only 32% of this planted trees were risen); *Salix viminalis* - up to 48 cm (and 80% were risen); *Populus nigra x*

Populus maximowiczii - up to 35 cm (about 50% were risen), *Populous trichocarpa x Populus koreina* – up to 30 cm (and 45 % were risen). These growing parameters of energy trees are represented on the **graph 10**.

Graph 10: Average heights and survivals of poplars and willows as of the middle of September 2007



From the **graph 10** is visible that the willow clones acclimated very well, better than poplar clones. *Salix alba* reached the highest height, even higher than *Salix viminalis*, but it survived much worse. By comparing clones of poplar, you can see that *P. nigra x P. maximowiczii* showed a little bit better results in both parameters; it grew higher and survived better.

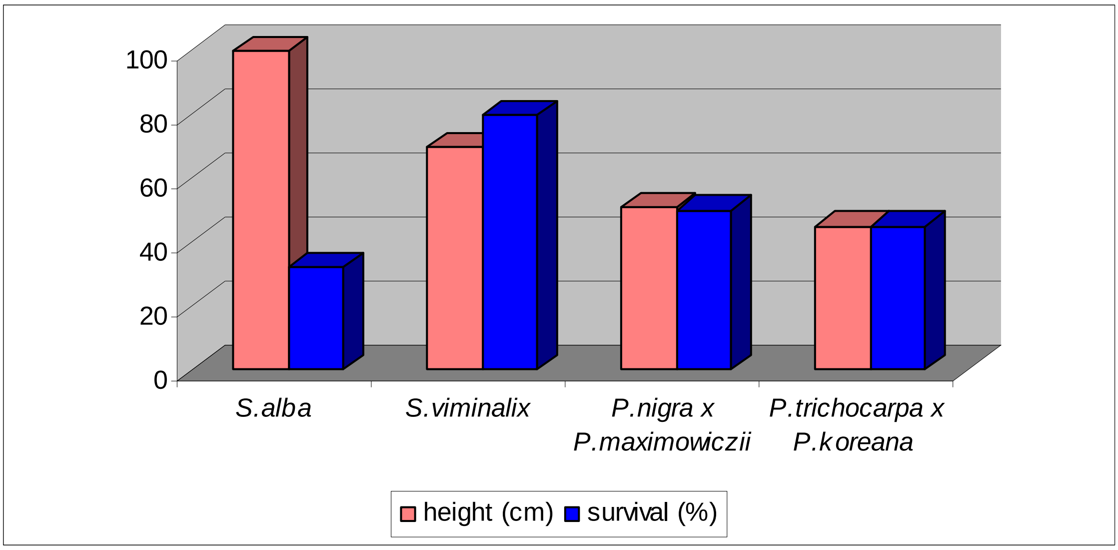
Unlike the grasses, the trees could survive dry summer thanks to the rooting system of trees that started to grow and develop before winter started. It's assumed that nearby lake played a very important and positive role. The experimental field with trees is 4 meters away from the lake and probably the level of underground water nearby the lake is high, so it helped trees to get water and survive drought.

- **<u>4th monitoring – end of November 2007</u>**

The monitoring was done 2 months after the last grass species sowing. Both grasses *Camelina sativa* as well as *Phalaris aquatica* developed from the seeds and young seedling stands appeared above the ground level.

The 7 months old energy trees continued to grow. The number of survived trees hasn't changed, that proves the creation of a good and healthy root system and high tolerance of the young trees to autumn frost. The average height of the trees was as following: *Salix alba* up to 100 cm, *Salix viminalis* - up to 70 cm, *Populus nigra x Populus maximowiczii* - up to 51 cm, *Populous trichocarpa x Populus koreina* – up to 45 cm. The situation of trees species growing is shown on the **graph 11**.

Graph 11: Average heights and survivals of poplars and willows as of the end of November 2007



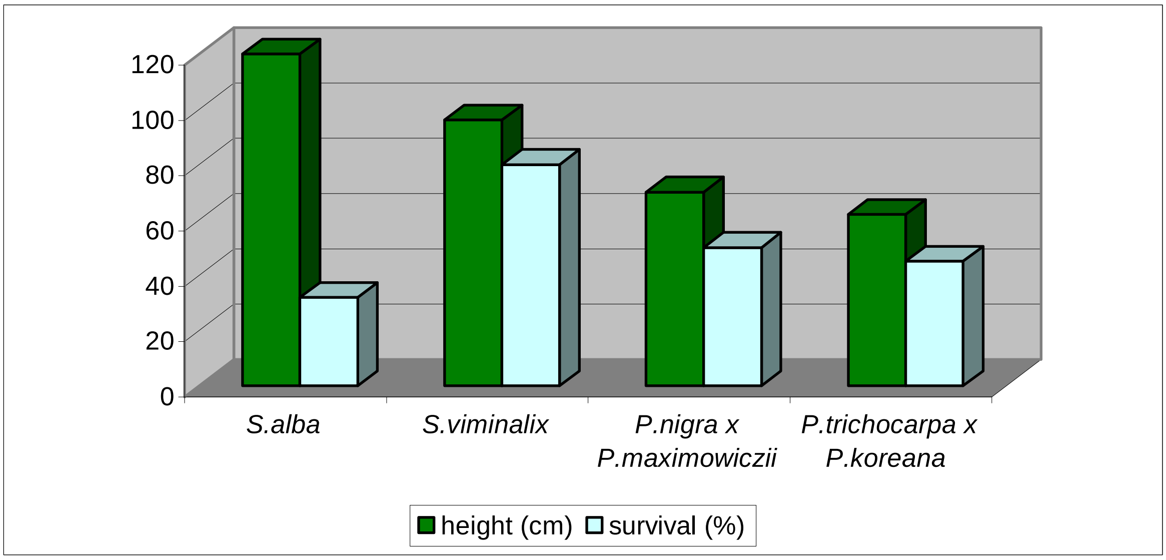
During 3 months from the last monitoring *S. alba* have increased to 27 cm, *S. viminalis* – 22 cm, *P.nigra x P. maximowiczii* – 16 cm, *Populus trichocarpa x Populus koreina* – 15 cm. It can be concluded that autumn climate was vary suitable for the trees growing.

- **<u>5th monitoring – beginning of April 2008</u>**

The monitoring was done at the moment when the energy grasses sown in the middle of September were about 7 months old. *Camelina sativa* grew densely tuft with height of 10 cm tall and *Phalaris aquatica* grew in a brushwood way with height of 30 cm. The grasses have shown good and intensive grow rate, in spite of late sowing.

The monitoring of 1 year old energy trees plantation showed that trees survived winter very good without losses, *Salix alba* has reached up to 120 cm in average, *Salix viminalis* - up to 96 cm, *Populus nigra x Populus maximowiczii* - up to 70 cm, *Populous trichocarpa x Populus koreina* – up to 62 cm. The main monitored parameters of the trees growing are represented on the **graph 12**.

Graph 12: Average heights and survivals of poplars and willows as of the beginning of April 2008



There is no biological difference between these trees can be seen on the **graph 12**, which is the number of stem shoots. Willows made an average of 2, 6 stem shoots, and while poplars almost only one shoot. It is possible to assume that this rate doesn't change even after the first scarfing. Poplars stem shoots are usually thicker then willows. For example, on the last monitor it was measured that the average diameter of poplar shoots near the main stem cutting was approximately 0, 7 cm; the diameter of shoots in the high middle of the tree was 0,6 cm; the average diameter of willow shoots near the main stem cutting was approximately 0,5 cm; the diameter of shoots in the high middle of the tree was 0,4 cm.

This and previous monitoring show that willow clones exceed the poplars by height and also survival in average. Survival is a very important parameter, because the higher survival leads to smaller expenses and higher yield of dry matter and higher energy yield too. On the whole, it is possible to say that the survival can be improved by using agrotechniques especially by preparing soil against weeds and also irrigation. In the first year the slow growth of poplars is not a binding deficiency, because it could later change into a success"well-growing" poplar.

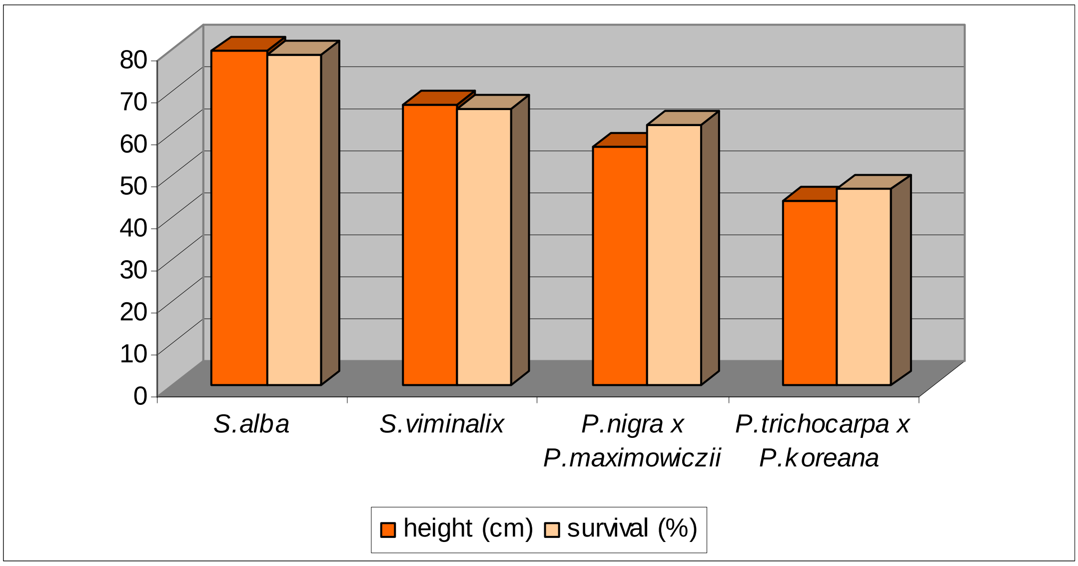
More photos from monitoring are listed in ANEXX 4.

5.5.4. Comparison of experiments on energy trees growing in Moldova and Czech Republic

Some years ago a similar experiment of energy trees growing was done in The Silva Taroucy Research Institute for Landscape and Ornamental Gardening in the town Pruhonice in Czech Republic.

On the **graph 13** are presented the results – the average heights and survivals of the same clones of energy willows and poplars.

Graph 13: Average heights and survivals of poplars and willow in the 1st year vegetation on the experimental field in Pruhonice.



By comparing the results from the **graph 13** and the **graph 12** it can be concluded that:

- Both experiments are similar in that willow clones in the first year of vegetation show better grow parameter than poplar clones.
- The experiment from Moldova confirmed the results of Czech experiment about the faster growing of *Salix alba* in comparison with *Salix viminalis.*
- Both experiments show that the average height and survival of *Populus nigra x Populus maximowiczii* is higher then of *Populus trichocarpa x Populus koreina.*
- The only difference is in survival of *Salix abla.* The survival rate of *S. alba* defined by Czech experiment is higher than the survival rate of *S. viminalis.* The experiment in Moldova shows much better survival of *S. viminalis.* Poor survival of *S. alba* in Moldova can be explained by that its plantation is situated on the field border near uncultivated land, so young stem cuttings could be attached by weeds.
- Having compared the experiments it is also visible that all trees in Moldova reach higher height than in Czech Republic. The possible explanation reasons are the soil and climate conditions of the location in Moldova are more suitable for these plants, but irrigation is requirement during heavy droughts there.

Comment: It should be mentioned that the land area near by the lake, where energy trees and grasses such as *Camelina sativa* and *Phalaris aquatica* were grown, was given into the property ownership of Aqua Agency. And the Moldavian State Agrarian University has allocated a new field for the experiment. In the middle of April 2008 there were planted new energy plants on the new field, including new and the same species planted in 2007; and energy trees were replanted from the old to a new experimental field.

6. Conclusions and recommendations

This M.Sc. Thesis consists of 6 chapters including introduction and conclusions and recommendations. The thesis was elaborated on the base of the collected information and my own experience from the Republic of Moldova. Accordingly to it, the following conclusions and recommendations could be formulated:

1. Moldova has a very vulnerable energy sector; it covers almost 97 % of the total energy supply from external sources. An important contribution to the increase of energy security of the Republic could be brought about by the utilization of renewable energy sources, such as wind, solar, hydro and bioenergy.

2. Apart form the big potential of renewable energy sources in Moldova, its development is still in a very low level, first of all because of poor and inadequate interest from the side of government, because of the lack of low and force, lack of experience and information and lack of appropriate equipment as well.

3. Bioenergy – the energy produced from biomass is not linked with the problem of distribution as it is with other renewable energy sources, biomass is available everywhere and its utilization is cheap. Thanks to it and due to the agricultural character of the country, biomass is seems to be the most effective energy source in Moldova.

4. The main existing source of biomass in the country with impressive energy potential is waste biomass represented by agricultural residues, but is not purposely used up to now.

5. In comparison with waste biomass the cultivation of energy plants for energy production could have the same or even greater importance in Moldova due to their higher energy yield and its invaluable and positive impact to soil, biodiversity, landscape and etc.

6. In April 2007 the first experiment on energy plants growing have been started in Moldova on the field of the State Agriculture University in Chisinau within the framework of development project of Czech University of Life Sciences Prague. The results of the first year showed that energy grasses planted before drought haven't risen, energy trees rise well, but their survival is low, energy grasses sown after drought are growing very actively now. So, it is recommended to irrigate the plants during very dry periods of year in order to increase their yields and survival.

7. I recommend to the University to widely use this experimental field for demonstration purposes in future and for miltidisciplinary education as well. Students of different faculties and specializations can have practice there. It is very important to expand the knowledge about energy plants as energy source by this way, due to the big gap of knowledge and experience in this question in the country.

8. Advisory services in the field of biomass energy use, energy plants cultivation and processing as well as new experiments on energy plants growing in order to detect the most suitable plants for future implementation will play and important role. Government support is needed, because government can organize a large information campaign.

It is too early to summarise the results of energy plants growing in Moldova as it is the only the beginning of field-tests. But necessity of that kind of experiment is really huge and already visible. I do not close this topic by M.Sc. Thesis elaboration; I would like to continue it during my following studies.

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8. List of Abbreviations

Bos basic oxygen steel

bbl barrel

bcm billion cubic meters

b/d barrels per day

Btu British thermal unit

CCGT combined-cycle gas turbine

CHP combined heat and power (plant)

CNG compressed natural gas

CO carbon monoxide

CO2 carbon dioxide

COG coke-oven gas

CV calorific value

DAZA Database of information about renewable energy recourses

DM dry matter

EHS electrical and heat generation stations

EJ energy yield

FFVs flexible fuel vehicles

GCV gross calorific value

GHG greenhouse gas

GJ gig joule, or one joule x 109 (see joule)

GJ/t gig joule per tone

GDP gross domestic product

Gcal gig calories

GWh/yr Giga Watt/year

IEA International Energy Agency

J joule

kWh kilowatt/hour, or one watt x one hour x 103

kV kilovolt

LNG liquefied natural gas

LPG liquefied petroleum gas; refers to propane, butane and their isomers, which are gases at atmospheric pressure and normal temperature

HEP hit and energy plant

MBtu million British thermal units

MJ/m3 mega joule/cubic meters

Mm3 million cubic meters

MPP main (public) power producer

MSW municipal solid waste

Mtce million tones of coal equivalent (1 Mtce=0.7 Mtoe)

Mtoe million tones of oil equivalent

MW megawatt, or one watt x 106

NCV net calorific value

Nm3 normal cubic meter

NOx nitrogen oxides

NPK Nitrogen, Phosphorus, Potassium

Ppm parts per million

PV photovoltaic

REPP Renewable Energy Policy Project

RES Renewable Energy Sources

tce tone of coal equivalent = 0.7 toe

TFC total final consumption

TJ terajoule, or one joule x 1012

toe tone of oil equivalent

TPES total primary energy supply

VFAs volatile fatty acids

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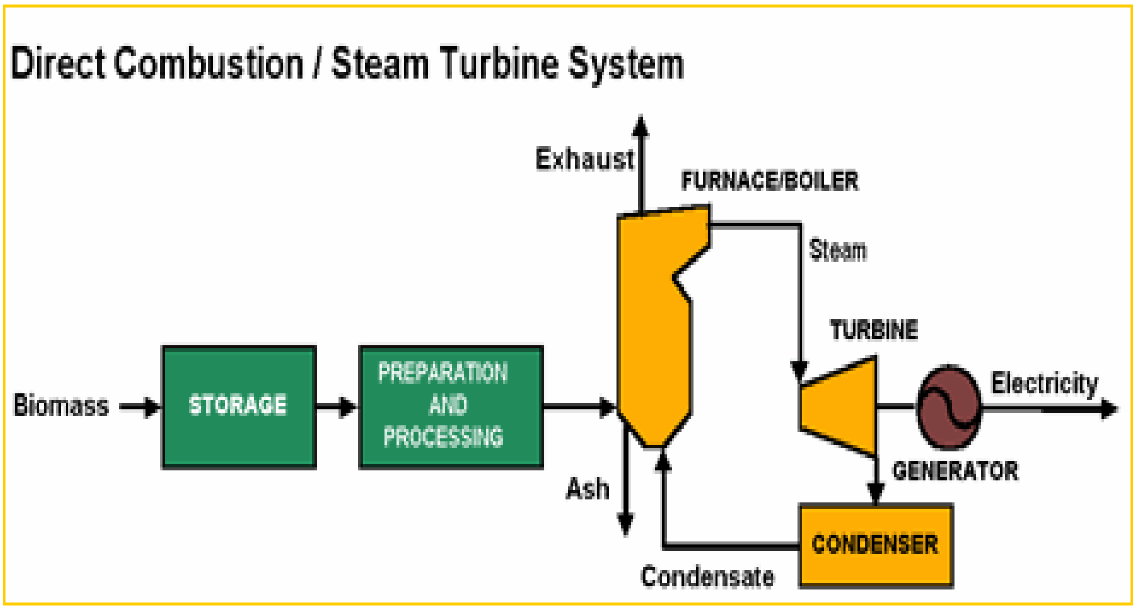
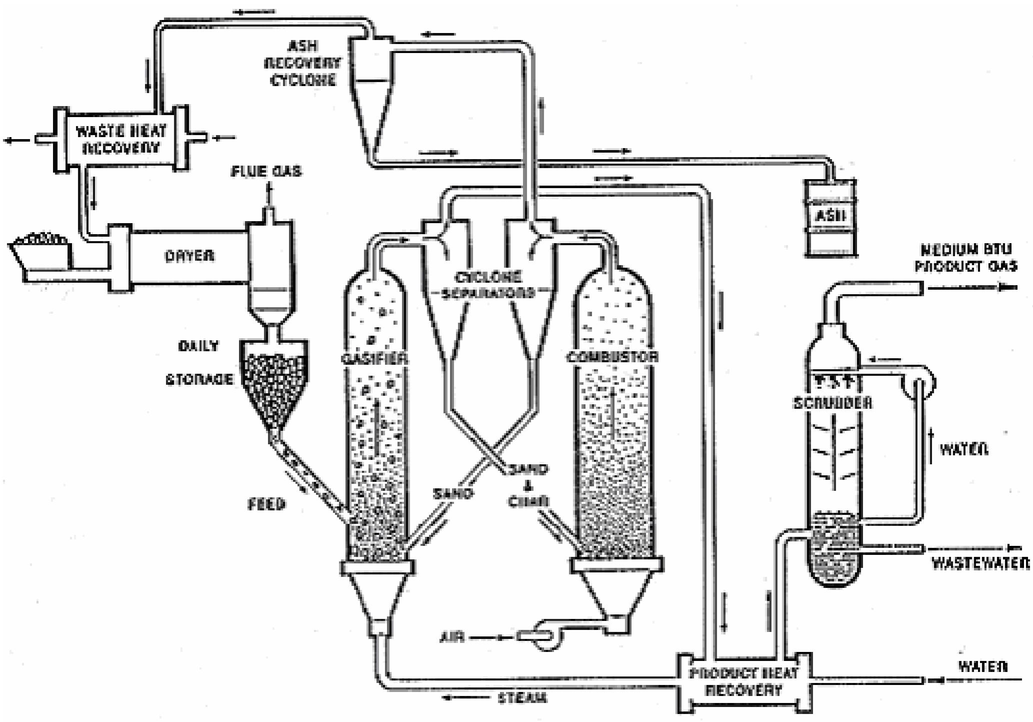
ANNEX 1

Schema 1: Direct combustion of biomass



Source: *U.S. Department of Energy*

Schema 2: Biomass gasification

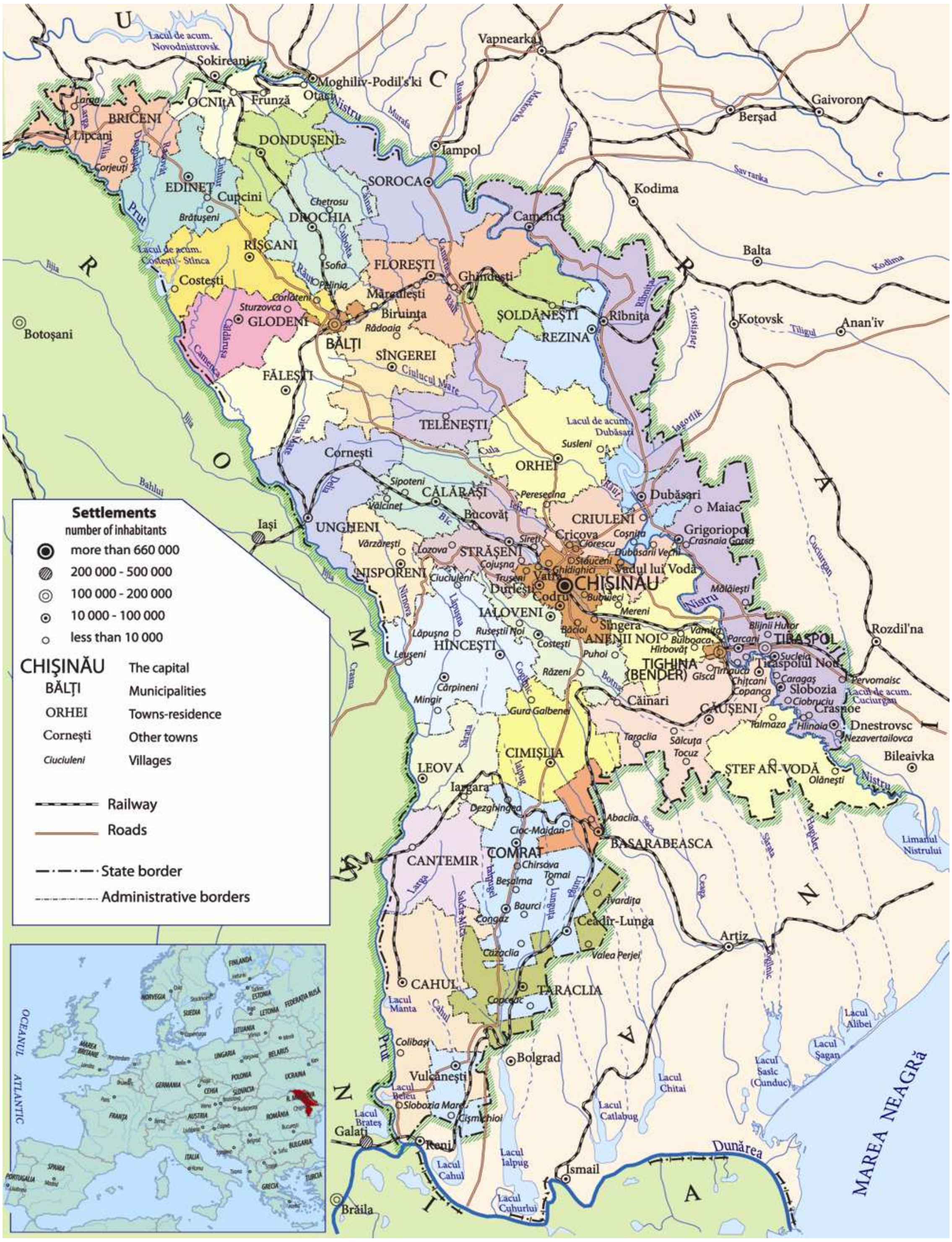


Source: *U.S. Department of Energy*

Schema 3: Briquetting press MULTIBRIK

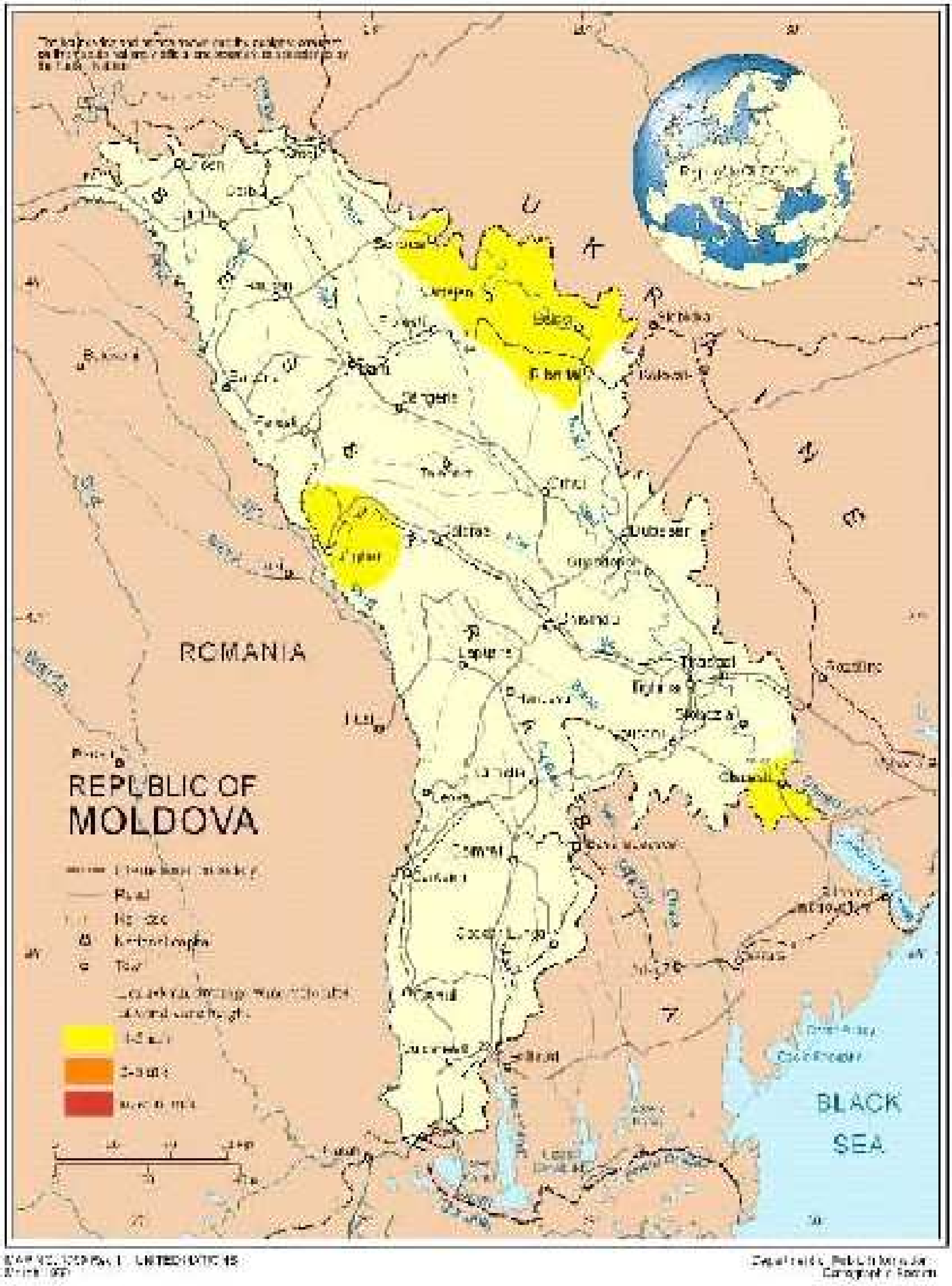
ANNEX 2

Map 1: Map of the Republic of Moldova divided into regions



Source: *Ministry of Environment and Natural Resources, 2007*

Map 2: Wind energy potential, wind map of Moldova

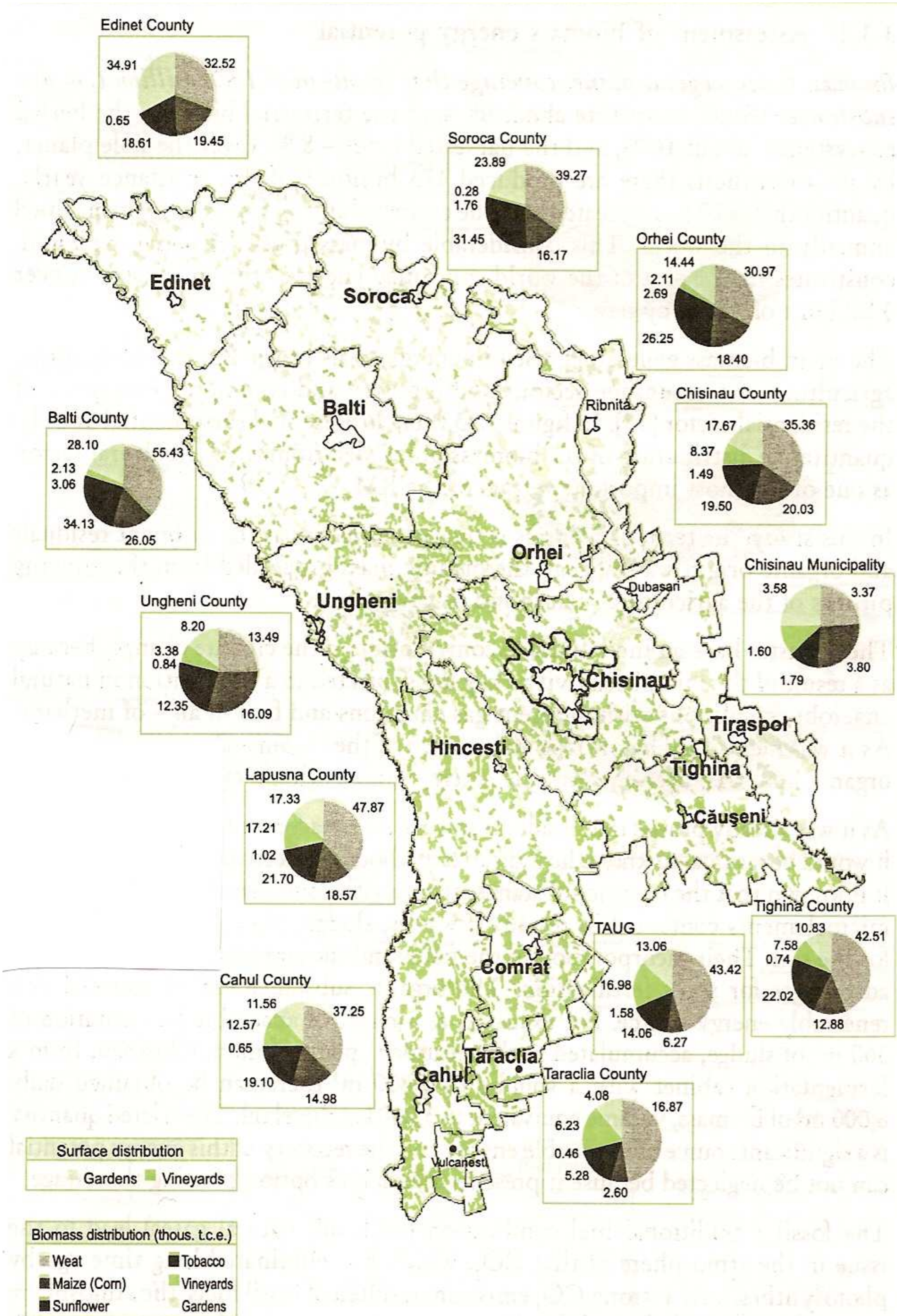


*areas with high potential wind energy are yelloow
Source: *Wind Atlas of Moldova, 1993*

Map 3: Hydropower potential, map of Moldavian rivers

Source: *European Bank for Reconstruction and Development, 2004*

Map 4: Biomass potential, map of biomass distribution in Moldova



Source: *TODOS and col., 2002*

ANNEX 3

Table 1: Energy prices in Moldova (2004) -electricity

Electricity		**Tariff without VAT bani/kWh**
1. Supply of electricity from producers		
	CHP-1	39.10
	CHP-2	35.19
	CHP North	38.56
	HPP Costesti	9.71
2. Services of dispatch and transmission through the network of State Company "Moldelectrica"		3.52
3. Supply of electricity by RE Chisinau, RED Center and RED South		
	for consumers connected to 110 kV lines and equipped with meters of high performance at the delineation points	55.00
	for residential consumers who leave in dwellings equipped (according to design) with electric stoves	60.00
	for other consumer categories	78.00
4. Supply of electricity by RED North and RED North - West		
	for consumers connected to 110 kV lines and equipped with meters of high performance at the delineation points	55.00
	for residential consumers who leave in dwellings equipped (according to design) with electric stoves	53.00
	for other consumer categories	70.00
5. Supply of electricity to residential consumers by RED North and RED North-West at optional tariffs		
	monthly consumption up to 50 kWh*	55.00
	monthly consumption over 50 kWh	1.65 Lei/kWh
Source: *National Agency for Energy Regulation, 2004*		

Table 2: Energy prices in Moldova (2004) –natural gas

Natural Gas		Tariff without VAT lei/1000 m3
1. Natural gas supplied from gas distribution stations (SDG)		913.49
Natural gas supplied by Moldovagaz JSC from the distribution pipelines to enterprises not belonging to Moldovagaz and supplying natural gas to final consumers		
	Distribution enterprises connected to high pressure pipelines	968.30
	Distribution enterprises connected to medium pressure pipelines	987.15
2. Natural gas supplied to combined heat and power plants (CHPs)		846.00
3. Natural gas supplied to specialized enterprises for generation and centralized heat supply		1000.00
4. Natural gas supplied to residential consumers with a monthly consumption of up to 30 m3 (included) per apartment (house)*		1080.00
5. Natural gas supplied to residential consumers with a monthly consumption exceeding 30 m3, other final consumers		1360.00
6. Natural gas transportation through mains		60.45
7. Natural gas distribution and supply through distribution pipelines		130.37
Source: *National Agency for Energy Regulation, 2004*		

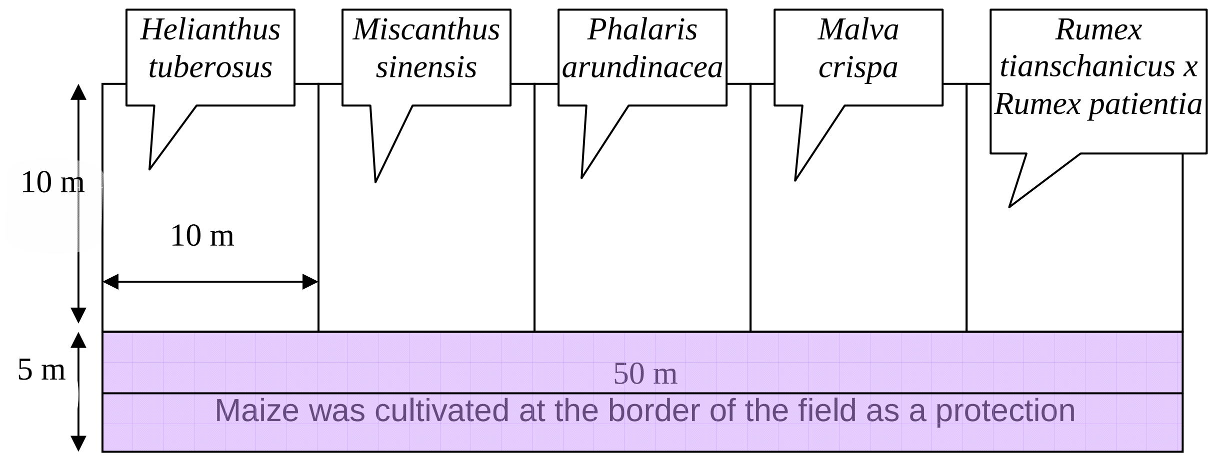
Table 3: Energy prices in Moldova (2004) –heat

Heat	Tariff without VAT lei/Gcal hot water
CHP-1	136.00
CHP-2	110.00
Heat supplied to consumers by CHP-North	299.00
Source: National Agency for Energy Regulation, 2004	

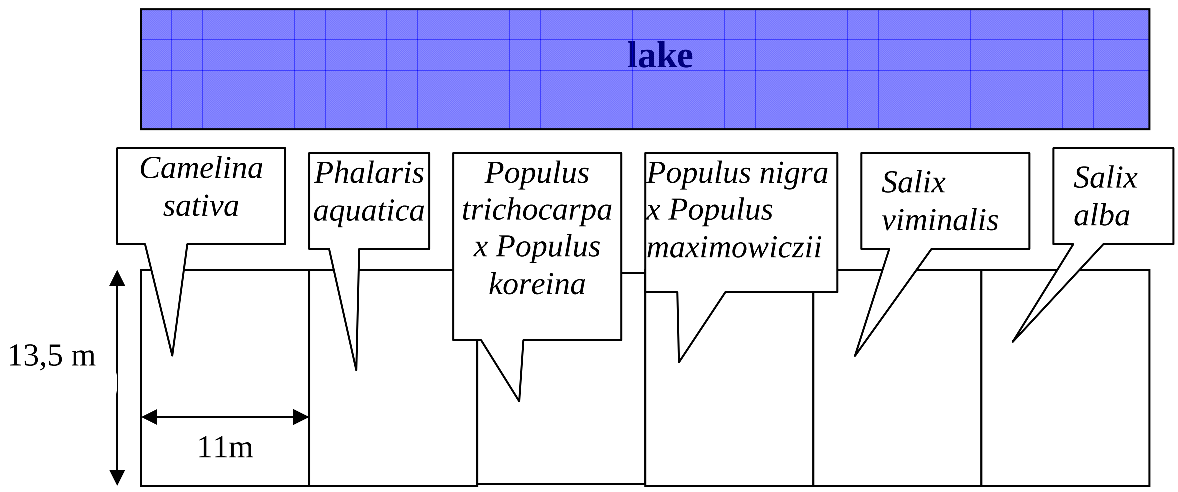
1 EUR = 15.0694 LEI (National Bank of Moldova, 22.10.05) 1 EUR = 16.1546 LEI (05.05.08)

ANNEX 4

Schema 1: Experimental field with energy grasses



Schema 2: Experimental field with fast-growing trees and energy grasses



Establishment of the field with energy trees, middle of April 2007

Planting of *Populus trichocarpa x Populus koreina*

Monitoring of growing energy trees, end of November 2007

Salix alba

Monitoring of energy grasses, middle of April 2008

Camelina sativa

Salix alba

Monitoring of energy trees, middle of April 2008

Salix viminalis