Petru TODOS, Ion SOBOR, Dumitru UNGUREANU,
Andrei CHICIUC, Mihai PLEȘCA

RENEWABLE ENERGY
Feasibility study

Chisinau 2002

CZU 620.91:662.997
E54

This study was elaborated within the project "Climate Change: Enabling Activity (Phase II)" implemented by the Ministry of Ecology, Constructions and Territorial Development in cooperation with UNDP Moldova under the Global Environment Facility financial assistance

Scientific editors:

Valentin Arion	Prof., Technical University of Moldova.

Coordinators:

Nicolae Stratan	National Coordinator, Vice-Minister, Ministry of Ecology, Constructions and Territorial Development of the RM
Margareta Petruşevschi	Program Coordinator, UNDP Moldova
Vasile Scorpan	Project manager, "Climate Change" UNDP/GEF Project
Andrei Perciun	Administrative assistant, "Climate Change" UNDP/GEF Project
Marius Ţaranu	Expert, "Climate Change" UNDP/GEF Project

The views expressed in this study are those of the authors and are not necessarily shared by the UNDP

Ministry of Ecology, Constructions and Territorial Development

Address: MD 2005, Chişinău, #9, Cosmonauţilor St.,
tel: (+3732) 228608, (+3732) 220748
fax: (+3732) 220748,
e-mail: *egreta@mediu.moldova.md*
web: *http://www.moldova.md*

UNDP Moldova

Address: MD 2012, Chişinău, #131, 31 August 1989 St.,
tel: (+3732) 220045
fax: (+3732) 220041
e-mail: *registry.md@undp.org*
web: *http://www.un.md*

ISBN 9975-9581-4-1

CONTENTS

INTRODUCTION

The XXth century has registered a succession of spectacular changes in all the domains. The technological progress of this century, based on great scientific discoveries in the domains of mathematics, physics, biology and informatics, has unleashed an unprecedented dynamism in the economical and social life, in society's evolution.

The rhythm of this economical development was determined to a greater extent by the expansion of fossil fuel energy utilization (oil, gas, coal). We can ascertain today that these fantastical progresses were at the same time generators of serious problems that were unknown to the humanity history till the modern age. The civilization has clashed with the environment, with the natural support of its own existence and of the life on earth, not only by the exhaustion of the natural resources of energy, but mainly by the deterioration of the quality of environmental factors – water, air, soil.

The acceleration of modern development has amplified the pressure on the nature that we remain dependent on. New forms of ambient imbalances – the reduction of the stratosphere ozone layer and the atmosphere warming – began to deteriorate considerably the ecosystems, population's health, etc.

In such a critical situation, its necessary to undertake urgent and drastic actions in order to avoid a possible ecological crisis and to ensure an environment of durable development for the next generations. All the world countries will involve in the progress of solution finding, independently of their territorial dimensions or economical potential. Terra should be laid out and treasured by common efforts, as it is a home of all world nations.

The paper reflects an attempt of arguing the possibilities of using three types of renewable energetic resources taking into account the climatic and economical conditions of the Republic of Moldova (RM) and implicit, the decrease of gas emission with greenhouse effect, which result in the process of electrical and thermal energies generation. There are also proposed judicious solutions for other problems that concern the insurance of the state's energetic security.

1. ENERGETICS: ENVIRONMENTAL AND SOCIAL PROBLEMS

1.1. World energy – strategical and technical dimensions

1.1.1. Energy sources and their comparative characteristic

Nowadays, the humanity benefits, in fact, of three categories of energy sources, that are based respectively on:

- fossil fuels combustion (coal, oil, gas)
- nuclear fission
- caption and renewable energy conversion (solar energy, wind energy, water potential energy, geothermal energy, etc.)

All these three categories of sources differ considerably between them: by their capacity to produce energy in the solicited conditions and time periods; by the price of the produced energy; by the seriousness of the impact on the environment.

a) **Fossil fuels** served as a base for the modern energy, during the last two centuries, thus representing the power support of industrialization and scientific-technical progress, realized in the specified period. Today, about 90% of the global energy demand is satisfied using fossil fuels.

The great calorific value, the stocking possibility in the necessary quantities for using at the right place and contemplated time, constitute the basic advantages, that determined the enormous use of this kind of fuel.

But, the numerous disadvantages characteristic to these energy resources among which two of the most terrible consequences:

- Limited volume of fossil fuels exploratory reserves;
- Strong impact on the environment, kept in silence, in the not so far away past

makes doubt itself the possibility of existence of the energy based on fossil fuels combustion in the near future.

Deposits of oil, natural gas and coal are indeed limited and in a short period these could be exhausted (*table 1.1*). Global fuel reserves will exhaust in 40-50 years, even at a constant consumption rate, equal to the nowadays one; the natural gas would be able to cover global energy necessities for an as well

Table 1.1. Global reserves of energy resources (1999 year)

Type of resources	Natural reserves*, Gtep	World production	Reserves. years
Oil	140.4	3.45	40.6
Natural gas	134	2.1	66
Coal ****	984,211	2.1	157
Uranium **	40->2,000	0.35	60->2,500***

* economical explorable
** depending on the used technology;
*** beginning with a consumption of 0,65 Gtep;
**** million tons.
Source: [7]

short period (60—70 years). The coal reserves are some more, but it's hard to imagine a modern energy based on coal with all the problems which concern extraction, transportation and its use (or any XXIst century transport that uses the coal as fuel).

The second cause which will determine fossil fuels energy sunset, much more rapidly and much before that the complete exhaustion of reserves is the impact on the environment. The process of coal, oil and natural gas combustion is accompanied by considerable emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), other gases and solid polluted particles (*table 1.2*). For example, at the combustion of one kg of coal it emits between 1.2-2.0 kg of CO_2.

Particularly the energy sector, with an enormous consumption of fossil fuels is responsible for the change of carbon dioxide balance in the atmosphere, gas with the great greenhouse effect. Moreover, the sulfur dioxide and nitrogen oxides cause acid precipitations, with an adverse impact on woods and agriculture.

Table 1.2. Specific emissions of gases and polluting substances resulted in the process of fossil fuels firing [4]

Polluant	g/kWh
CO_2	480-965
SO_2	0.35-16
NO_x	0.9-5.3
Ash	55
Dust	0.1

b) Nuclear energy

The nuclear energy era starts in the '70's of the XXth century, knows a spectacular and promising development in the '80's, conquering the electrical power sector of the most developed European countries, USA and Canada at the end of the '90's (*table 1.3*).

The catastrophe of Chernobyl nuclear power plant (1986) has made doubtful the future of the fission nuclear energy. The greatest world's countries found themselves forced to stop the nuclear programs, and to quit the idea of constructing new nuclear energy units, because of: possible explosions risk, amplified by the international terrorism widening, the problem of collection, storing and processing

Table 1.3. Electricity production at the nuclear power plants in the EU Member States [7]

Country	No. of units in exploitation at 01.01.2000	Output in 1999	
		TWh	% of total
Belgium	7	46.7	57.7
Finland	4	22.1	33.1
France	58	375.0	75.0
Germany	20	160.8	31.2
the Netherlands	1	3.6	4.3
Spain	9	36.5	29.9
Sweden	11	70.2	46.7
Great Britain	35	87.7	26.0
EU-15	145	822.6	34.6

of radioactive wastes problems, proceeded from nuclear power and the plants problem of their preserving after the expiration of operation period [7].

The operation of nuclear power plants is not accompanied by harmful gas emissions, but the noxious nuclear raw material is sufficient for many of centuries ahead (*table 1.1*).

On long term, nuclear energy has chances to restore its at all negligible position, especially in electrical energy production, but this is going to happen only after the elaboration of new technologies, able to assure both the reliable operation of nuclear power plants and radioactive wastes processing.

c) **Renewable energy sources** (RES) are:

- Wind energy;
- Solar energy;
- River hydraulic energy;
- Energy of ebb and flow, and sea waves;
- Geothermal energy;
- Biomass energy.

The main criterions, which determine the RES operation perspectives, are:

- an uniform wide spreading and the access to their utilization for the majority of countries;
- the placement of RES near the centers of consumption and as a result the lack of necessity of transporting the energy at large distances; population access both at the production and utilization of energy;
- the majority of RES are non-polluting.

These important advantages determined the industrialized countries, but also a lot of developing countries, to build, step by step, a new energy system, which would consider non-traditional SRE. The disadvantages that have been retaining for a long time the implementation of RES on a large-scale, are:

- RES energy is dispersed, fact that determine significant costs of final energy production facilities;
- Non-uniformy distribution in time;
- Lack of storage possibilities, and constitution of reserves.

Due to the fantastical progresses of the last two decades, the technologies and installations of power and thermal energy of RES can compete from the economical point of view with those traditional.

Undoubtful is the fact that in the future, RES will represent an important component of energy systems.

Among the renewable energy sources, hydro-electric engineering, occupies a special rank. At the present moment, hydro-energy resources assure about 3% of the total energy demand, representing about 20% of the power energy produced on the international scene.

It is foreseen that nearly in 2020 year, RES will cover from 3-4% (the "pessimist" variant) to 8-12% (the "optimist" variant) from the global energy consumption [8].

In the XXI[st] century, global energy will register an important increase of renewable energy weight, as well as a considerable decrease of the weight of the energy resulted from fossil fuels firing.

1.1.2. Energy consumption and generation

The present world energy consumption constitutes about 9,400 Mtoe (Megatons of oil equivalent). During the last two decades, the energy consumption increased approximately by 1.35 times and according to valuations [4, 6, 7, 8, 13], it will continue to grow (table 1.4). This growth will be realized enough slowly in the industrialized countries (about 1% per year) and much more intensive in big developing countries (about 4,5% per year). The related countries are following the industrialization way crossed by the industrialized countries, emphasizing the energy forcing. Thus, towards 2050 is expected a doubling of global energy consumption (comparing to 1990), in parallel with the population and the GDP growth. It should be mentioned the fact that the consumption per capita at the global level will remain for a long period at the 1990 year level (*table 1.4*). And the enormous difference of per capita consumption will change as well very slightly, between the wealthy and poor countries [3].

The fossil fuels share in the global energy consumption represents 84,6%. The long term valuations [7, 8, 13] demonstrate that in the following 20 years fossil

Table 1.4. World demography, economy and energy

Demographical and economical indexes	1980	1990	2000	2010	2020
Population (pop), mil.	4,314	5,249	6,150	7,027	7,893
GDP, bil. $US*	20,221	27,383	35,138	50,187	69,945
GDP/pop, thous $US per capita*	4.69	5.2	5.7	7.1	8.9
Energy consumption (EC), mil. toe	6,787	8,184	9,263	10,951	12,611
EC/pop, toe per capita	1.573	1.603	1.535	1.565	1.601

*for 1990 rate

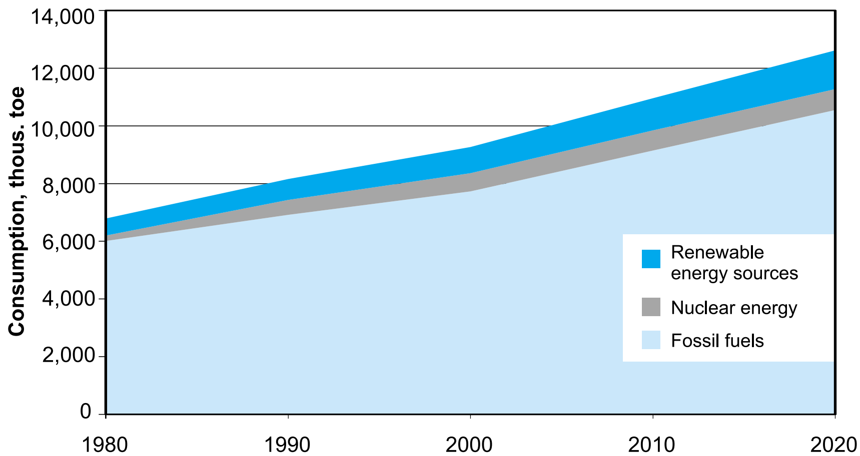


Figure 1.1. World energy consumption till 2020 (Mtoe). Source [8]

fuels will remain the basic world energy source (*figure 1.1*). The nuclear energy share will decline slowly from 6.7% in 2000 to 5.5% in 2020, but the renewable energy sources share will increase to 10.5% in 2020.

The correlation between the consumption of oil, natural gas and coal will suffer essential changes (*figure1.2*). There is also supposed a reduction of oil consumption to 36.2% from the total consumption towards 2020; the solid fossil fuels share (coal, lignite), will not outrun 28.7% up by that time. These reductions will be compensated for owing to the increase of the gas consumption (from 24.4% in 1990 to 35.1% in 2020).

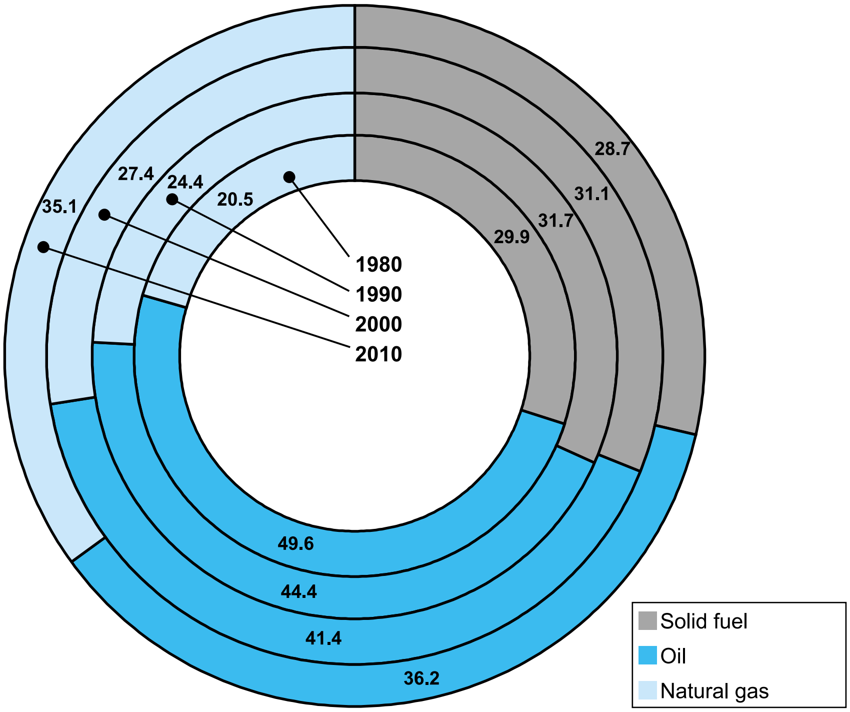


Figure 1.2. Consumption structure of fossil fuels (%) by types

In figure 1.3 is represented the energy consumption distribution on specific groups of countries (OECD, Former Soviet Union (FSU), Asia).

Although natural deposits of fossil fuels are discovered permanently, the danger of their exhaustion is still present (*table 1.1*)

The quality of available resources depreciates year by year, instead the cost of their obtaining and transportation is rising. The impact of producing and using this kind of fuels on the environment becomes more and more serious. The fossil fuels deposits are spread very non-uniform all over the globe. Table 1.5 reflects that more than one third of oil and natural gas reserves are concentrated in the Middle Orient, zone with a population of several percentage of the world

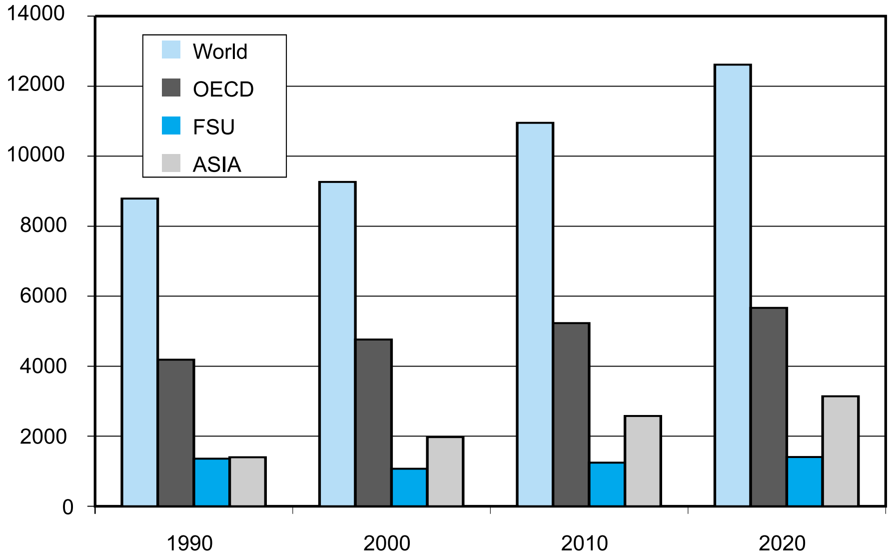


Figure 1.3. Energy consumption distributed by groups of countries

population. Some of the greatest world's countries (China, India) with a population of some 2 billions, dispose only of 2.8% from the total oil reserves, 1.3% from the total natural gas and some small reserves of coal (*figure 1.4*).

There is a great disproportion between the energy production and its consumption. The Middle Orient and Russia possess over 70% of global oil and natural gas reserves, but their own consumption constitutes about 15%. OECD countries cover more than 60% of their own consumption of primary energy from import.

EU member states dispose approximately of 2% of world fossil fuels reserves (oil and natural gas, under North Sea). It is considered that in 50 years these reserves will be exhausted [6, 7]. The uranium available deposits are also enough limited.

The primary energy production constituted in EU in 1998 about 753 Mtoe that represents 52,5% of consumption. The difference of 679 Mtoe was covered from import: the oil is being imported preponderant from OPEC countries (51%), and gas from FSU (41%), Norway (21%) and Algeria (25%).

The EU energy market dependence on the gas and oil import will intensify more in the future decades.

Table 1.5. Energy resources by groups of countries comparing to the world reserves (%)

Fuel	EU	FSU	MO	China	India	Aus.	NA	Jap.	CSA	Africa
Oil	2	6.3	65.4	2.3	0.5	0.3	8	0	8.6	7.2
Natural gas	3.5	38.7	33.8	0.9	0.4	0.9	5	0	4.3	7.7
Coal	12.4	23.4	0	1.6	7.6	9.2	26.1	0.1	2.2	6.2
Uranium	3	29	N/A	N/A	2	20	18	1	7	17

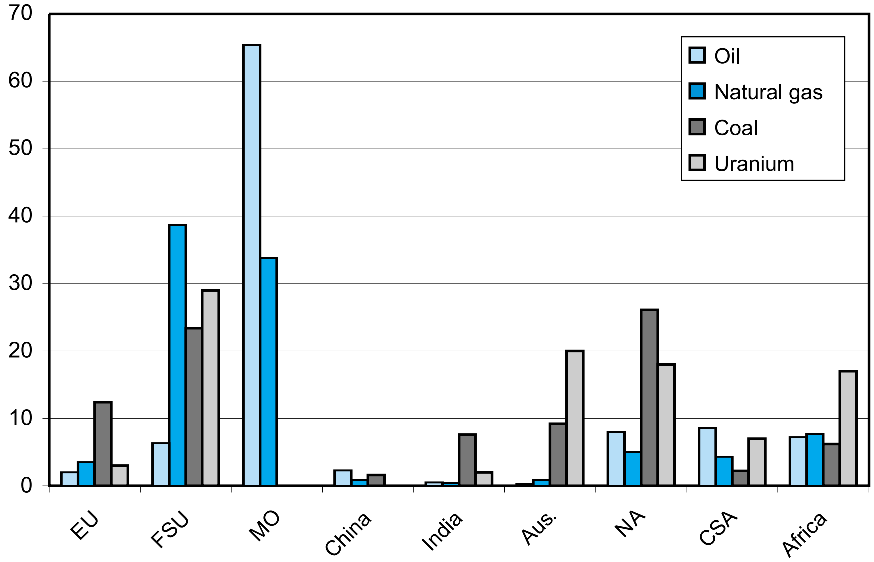


Figure 1.4. Energy resources by groups of countries in correspondence with global reserves (%)

EU - European Union, FSU - Former Soviet Union, MO - Middle Orient, Aus. - Australia, NA - North America, CSA - Central and Southern America.

The permanent confrontations between the primary energy consumers and producers have caused several economical disturbances at the global level, starting with the oil crisis in 1973. At present, the security of energy supply has transformed into a strategical state problem of the industrialized countries.

1.1.3. The environmental impact of the energy sector based on fossil fuels consumption

The existence of a tight correlation between the process of energy production and utilization and the effect of the environment pollution, which resulted from this process, have been well known before the appearance of the climate fluctuation phenomenon. There is no process of energy generation from organic fuels without any impact on environment.

At the fossil fuels combustion either in internal-combustion engine or ion reaction turbines or boilers, during the process of production of thermal and electrical energies there are emanated considerable quantities of polluting gases (CO_2, CO, SO_2, NO_x) and solid particles.

The quantity of emissions depends on the type of the fuels, the used technology, installations efficiency and on the modalities of the environment protection. As an example, in table 1.6 are presented data regarding natural gas emissions and polluting substances specific to the coal-fired power plants in 3 EU countries [4].

In table 1.7 there can be found important data for comparing specific emissions of carbon dioxide, as gas with the largest greenhouse effect, at the production of one kWh of electricity at power plants with different production cycles.

Table 1.6. Emissions in g/kWh, specific to power plants on fossil fuels combustion, in three EU Member states

Types of emissions	the Netherlands (g/kWh)	Great Britain (g/kWh)	Denmark (g/kWh)	Average (g/kWh)
CO_2	272	936÷1,079	850	964
SO_2	0.32	14.1÷16.4	2.9	0.38÷16.4
NO_x	0.89	2.5÷5.3	2.6	0.89÷5.3
Ash and cinder	NA	NA	55	55
Dust	NA	NA	0.1	0.1

Table 1.7. CO_2 emissions from utilization of different electricity production technologies, g/kWh

Technology	CO_2 emissions
Coal combustion	954
AFBC	963
IGCC	751
Oil combustion	726
Natural gas combustion	484
OTEC	304

Sulphur dioxide and nitrogen oxides cause acid precipitations, with a very dangerous impact on human health, woods, crops and especially on ecosystems (terrestrial and marine).

The losses that are the result of acid rains are estimated to 6,000 Euro per ton of SO_2 or NO_x emissions [4]. In this case, it's not about a local impact, as the gases and the solid polluting substances are spread at hundreds of km from the place of their emission. The slag and the dust, together with other pollutants, form the so-called photochemical smog.

If the SO_2, NO_x emissions can be significantly reduced, using different kinds of fuel processing technologies and clearing of funnel gas, it is more difficult to decrease the specific CO_2 emissions generated from organic fuels combustion at the energy production. It should also be stressed out that CO_2 is an inevitable product at the combustion of organic matters.

Carbon dioxide is the gas with the largest greenhouse effect. The CO_2 blanket from the atmosphere act as an unidirectional filter for the sun rays and for those reflected or irradiated on the Terra's surface. The sun rays (with short wavelength) cross freely the atmosphere, while the rays issued by the Terra's warmed surface (infrared rays with long wavelength) are rejected (ireflected) by the CO_2 layer. The increase of CO_2 percentage in the atmosphere unsettles Terra's thermal balance. The modifications of only decimal exponent of the global average temperature are sufficient for unpredictable climate fluctuations.

The industrialization and the transport, based on an intensive energy consumption, at the same time with demographic outburst, conducted in the last 100 years to a great increase of anthropogenic CO_2 emissions ant this tendency continues to amplify. Thus, the coal, gas, oil products combustion generate yearly emissions of about 6 billion ton of CO_2 in the atmosphere. The carbon dioxide concentrations in the atmosphere increased by 30% towards the preindustrial period. If the present emissions rate would maintain also during the XXI century, the CO_2 concentration in the atmosphere would double, achieving an inadmissible level.

In fact, there have been started to be noticed the weather conditions changes that confirm the global climate modification: intensive glacier thawing, unprecedented floods, tornado, cyclones, droughts and maximum temperature in Europe and other parts of the world. In such a situation there are necessary urgent measures to stop this ecological decline that could lead in a short historical period to catastrophic and irreversible changes.

The problem of limitation CO_2 emissions in the atmosphere and the concrete actions regarding their reduction were formulated in the Kyoto Protocol.

In 1990, 75% of CO_2 emissions, resulted from the energy production, which account for the industrialized countries (table 1.8). USA generate approximately a fourth thirds (22%) of the global volume of emissions, that is 5 ton yearly per capita. The quota of CO_2 emissions is also enough high in the EU countries (*table 1.8*).

Table 1.8. Global CO_2 emissions (Mt), related to energy production

Countries and groups of states	1980	1990	2000	2010	2020	2020/1990, %
OECD including EU USA Japon	10,424 3,412 4,987 1,004	10,739 3,248 5,085 1,167	11,833 3,366 5,601 1,324	1,2847 3,555 6,007 1,405	1,3811 3,721 6,378 1,453	1.29 1.15 1.25 1.25
SEEC	1,174	1,020	870	932	984	0.96
FSU	3,303	3,710	2,827	3,239	3,614	0.97
Latin America	592	689	953	1,251	1,649	2.39
Africa	440	689	917	1,294	1,707	2.48
Asia including China Middle Orient	2,425 1,488 370.2	4,083 2,398 697.3	5,773 3,218 804.2	7,514 4,001 1,087.9	9,064 4,644 1,337	2.22 1.93 1.92
Total	**18,818**	**21,716**	**24,074**	**28,258**	**32,283**	**1.49**
quota OECD	*55.4%*	*49.5%*	*49.2%*	*45.5%*	*42.8%*	

No doubt, that the energy production is the main source of emissions of greenhouse gases. Especially these constituted about 80% of the total emissions from EU countries in 1990 (reference year). The emissions are tightly connected to the quantity of consumption and to the type of the fossil fuels used (*table 1.9*).

For example, about a third of the CO_2 emissions volume in EU proceed from the thermal energy and electricity production. In 1990, to the transport sector corresponded a fourth of the EU emissions and this share continues

Table 1.9. CO_2 emissions in EU in 1990 (year of reference), in Mt

Sectors	Type of fuel			Total
	Solid fuel	Oil	Natural gas	
Thermal power plants	630	120	150	***900***
Industry	190	140	180	***510***
Transport	0	840	0	***840***
Residential sector	40	300	300	***640***
Other sectors	0	140	30	***170***
Total	***860***	***1,540***	***660***	***3,060***

to grow (table 1.10). The studies demonstrate that in the lack of efficient policy actions, this sector will determine the highest growth of CO_2 emissions till 2010 (year).

Table 1.10. European Community - CO_2 emissions (forecasts [8]) related to types of fuels and sectors

The origin of CO_2 emissions	1992	2000	2010	2020	Accumulation 1992-2020
By types of fuels:					
1. *Solid fuels*	993	922	824	775	24,748
2. *Liquid fuels*	1,513	1,565	161	1,646	46,107
3. *Gas*	630	812	1,022	1,187	26,975
By sectors:					
1. *industry*	567	575	593	640	17,287
2. *residential*	658	617	644	1,527	18,734
3. *transport*	793	872	951	970	26,297
4. *heating*	7	13	11	11	309
5. *energy*	137	140	138	134	3,999
6. *generation of power*	973	1,050	1,119	1,195	31,263
Total CO_2 emissions	***3,136***	***3,299***	***3,458***	***3,608***	***97,830***

The UNO Member States, agreed to reduce in the frame of Kyoto Protocol with 8% total CO_2 emissions and other 5 greenhouse gases with till 2008-2012, in comparison with the level of the reference year (1990).

There was established an agreement, between the EU Member States, accepted by the European Commission (March, 1997), regarding CO_2 emissions reduction by 15% for the Community. It was included in the document that was voted at the UNFCCC Conference of Parties at Kyoto. In the related document there are established the program-shares for each of the 15 EU Member States, regarding global reduction of CO_2 emissions.

The Member States with a lower development level (Portugal, Greece, Spain) were allowed a significant increase of energy consumption. Therefore, in these states the CO_2 emission volume will be greater comparing to the reference year, while the most developed countries (Luxemburg, Germany, Austria, Belgium, the Netherlands, Great Britain, Italy) have undertaken significant CO_2 emission reductions (up to 30%).

Each of the EU Member States defined specific actions in their national programs [4], taking into account the features of their own energy system and the possibilities that they dispose of, among which could be mentioned the following three, being the most important:

- energy production facilities rehabilitation, including the larger utilization of cogeneration systems;
- actions of increasing energy efficiency, that would allow to decrease consumption and emissions at the same quantity;
- the implementation on a large-scale of renewable energy sources (power and thermal energy), non-polluting, which does not issue greenhouse gases.

One of the first measures oriented on the GHG emissions reduction is the step-by-step passage of power plants from coal and oil combustion to operation on natural gas. On the natural gas combustion process, the CO_2 specific emissions are twice reduced comparing to those derived from coal combustion and of 1.5 times in comparison with emissions resulted from oil combustion (*table 1.7*). Concomitantly, the much more reduced cost of energy technology, based on the consumption of natural gas, should be also considered.

In this context the measures focused on the increasing of energy efficiency in industry, transport and housing servicesare also of great importance. But the most efficient way of reducing CO_2 emissions is the energy production from renewable sources. As it is mentioned in the Report of EU Energy Council, these kind of installations are supposed to be operated in the context of a unique energy policy, which will fit harmoniously in the ambient and sustainable development aspects.

1.1.4. Environmental advantages of the renewable energy sources

The RES represents the chippest and the securest way of reducing polluting gas emissions, when producing electrical and thermal energies.

For example, a 600 kW wind turbine, in average wind conditions, which is characterized by an utilization coefficient of the installed capacity equals to 0.3, could contribute during the life period of 20 years, to the CO_2 emissions reduction by 20-36 thousands tons, produced in the case of a coal or oil combustion based power plant.

In the process of producing electric power, mechanical and thermal power from SRE, there can be used the following convertion technologies:

Wind energy – to electric or mechanical energy;
Solar energy – to electric or thermal energy;
Hydraulic river energy – to electric or mechanical energy;
Geothermal energy – to thermal or electric energy;
Biomass energy, including organic wastes – to electric or thermal energy.

At present, the most largely used sources are: hydro energy, wind energy, solar energy and that of biomass convertion. Specific to all the listed technologies is the absence of CO_2 emissions. Only at the biomass combustion it is issued a CO_2 quantity equivalent to the amount of CO_2 emissions removed by regrowth of the plants, thus registering a null final balance of CO_2 emissions.

The hydroelectric power plants produce nowadays about 22% of the global electricity volume. Because the river resources are almost completely exhausted, it can't stake on a considerable increase of hydroelectric power plants related to the present one. The geothermal energy reserves are less exploited for the moment.

The greatest prospect is offered by technologies of producing electricity using the wind (power) as well as the thermal solar and photovoltaic instalations.

Each of these technologies found its developing niche, the area where they can compete with traditional technologies of obtaining fossil fuels energy.

Wind energy has a good prospect for a large-scale electricity production. Aerogenerators with o power from 0.6 to 3 MW associated in large groups (wind farms) and connected to the electricity supply network, generate electricity in paralel with the thermal power plants, hydraulic and nuclear plants. It is supposed that wind energy will assume a significant part of the electric power share, produced curently at the nuclear plants and those based on fossil fuels combustion.

Photovoltaic converters transform the solar energy directly into electricity. The most advisable beneficiaries, in this case, are the isolated electricity consumers, that don't have access to the public network.

The solar collector represents the most modern technologies of capturing the solar energy and its convertion into thermal energy for heating/cooling apartment houses and obtaining warm water for housekeeping.

The national programs stipulate an intensive increase of the energy produced from RES and according to some optimist forecasts, it is considered that over a half of century up to 50% of the whole electricity production will be generated by wind. A considerable part of thermal energy for heating the apartment houses and the housekeeping water, will be obtained from solar collectors, biomass and wastes. It is also relying a lot in the near future on the large utilization of combustion elements based on hydrogen, which can be obtained of gas or water, using for example electricity produced by the wind plants.

RES represent an extremely important advantage: that of not polluting the atmosphere with CO_2 and other anthropogenic emissions. Moreover, they are spread all over the globe much more uniform than the fossil fuels resources. Each country of the world dispose of certain solar, wind, geothermal, biomass and hydraulic energy resources.

The development of the energy based on these resources would consolidate the security of energy supply of many states. A new energy system, less centralized that takes into account also RES could be able to spread on a large scale energy services, contributing to the development of the poorer regions and to the creation of new work place on the rural areas.

Because the installations of renewable energy are of small sizes unsignificant comparing to the present power plants, this kind of installation could stress out the population's interest.

Both the priorities relating to the environment protection and the advantages in the social sector offered by the energy based on RES are opening new prospects for these energy production modalities.

Conceiving a new energy system, suitable to the XXIst century, could contribute to the reestablishment of a balance – unfortunately neglected – between the energy, human wealth and environment. It is not right for energy to be treated as a merchandise that should be consumed, not considering the consequences. No doubt that energy should be exploited by humanity, but it should be done choosing the ways that run counter to the relations between the society and the environment. Only like that, we will be prepared to prevent the ecological catastrophes that could challenge the sunset of certain civilizations who didn't know to appreciate the dowry left by nature.

BIBLIOGRAPHY

1. *State of the World 1999*. A World Institute Report on Progress Toward a Sustainable Society. Lester R.Broun – project director, 1999.
2. *State of the World 2000*. A Worldwatch Institute Report on Progress Toward a Sustainable Society. Lester R.Broun – project director, 2000.
3. Christopher Flavin, Nicholas Lenssen*, Energetic Wave, Guide for the imminent energetic revolution. Humanity global problems,* Technical publishing house, Bucharest.
4. *Wind Energy – the Facts,* European Commission, EWEA, 1999.
5. *The Shored Analysis Project Economic Foundations for Energy Policy,* vol.nr.2.
6. *Green book – Toward a European strategy of security energetic provision.* European Commission.
7. *Green book on the energy provision security. Technical document,* European Commission.
8. Direction general for Energy (DG XVII). *Energy in Europe. European Energy to 2020. A scenario approach. Special ISSUE – Spring 1996.*
9. Second Report to the Council and Parliament of Europe on the harmonization requirements. Directive 96/92/CE *concerning common rules for the inner electricity market.*
10. The Danish Wind Industry Association. *Annual Report.* www.windpower.dk/publ/annu9900.pdf
11. *The wind turbine market in Denmark by Soren Krohn*. www.windpower.dk/articles/vtmindk.html
12. *Danish wind Turbines: An Industrial Success Story* – by Soren Krohn. www.windpower.dk/articles/success.html
13. *The Shored Analysis Project Energy in Europe*. Foundation for Energy Policy Special Issue. European Commission, 1999.

2. PRESENT STATE AND THE DEVELOPMENT STRATEGIES OF THE REPUBLIC OF MOLDOVA ENERGY SECTOR

2.1. Overall performance of the Republic of Moldova's power system

The Republic of Moldova has been crossing a long transition period to the market economy. Towards 1998 GDP declined to the level of 35% comparing to the reference year (1990). The industrial output decreased in the greatest proportion, earlier the industry having been the largest energy consumer.

As a consequence, simultaneously with the economical decline, the energy consumption decreased significantly (*table 2.1*)

In 2000 the total consumption of primary energy resources in the Republic of Moldova (the right side of Dnestr) constituted 3.86 Mtce or 1.05 t.c.e. per capita.

Specific to the RM is the absence of own energy resources, excepting some modest water power and biomass resources, exploited at the hydroelectric power plants of Dubasari and Costesti. About 98% of the total consumption of energy resources from the country is covered from import. Thus, in the RM natural gas and oil import from Russia constitutes 100%, coal import from Russia and the Ukraine –100%, the electricity being mainly acquired from the Ukraine and an insignificant quantity from Romania and Russia. All the transporting ways of the gas and liquid fuels, also cross only one country (Ukraine); electrical energy relations with the West are very limited (only three power lines of 110 kV with Romania).

The energy dependence diminution represents a key-problem of the state security of supply. There exist a general solution to this problem – import diversification (countries and ways) sources. On a long term an important contribution to the increase of energy security of the RM could be brought by the exploitation of the own energy resources, as well as the a large scale use of RES (wind, solar, biomass) that are disposed by the country.

The consumption structure by types of energy sources in dynamics is presented in figure 2.1. It can be observed a considerable increase of the gas share (more than 55%), almost a total reduction of the coal consumption and an approximate increase about 10% of the electricity consumption share. The energy resources consumption by sectors is reflected in figure 2.2.

Table 2.1. Domestic consumption of energy resources in the Republic of Moldova

Types of resources	Years		
	1995	**2000**	**2005** (forecast)
Total primary resources, in millions t.c.e.	5.53	3.86	5.0
Including:			
Natural gas, millions t.c.e.	2.97	1.22	3.06
Coal, millions t.c.e.	0.67	0.16	0.44
Electricity energy, billions kWh	5.37	3.38	6.00

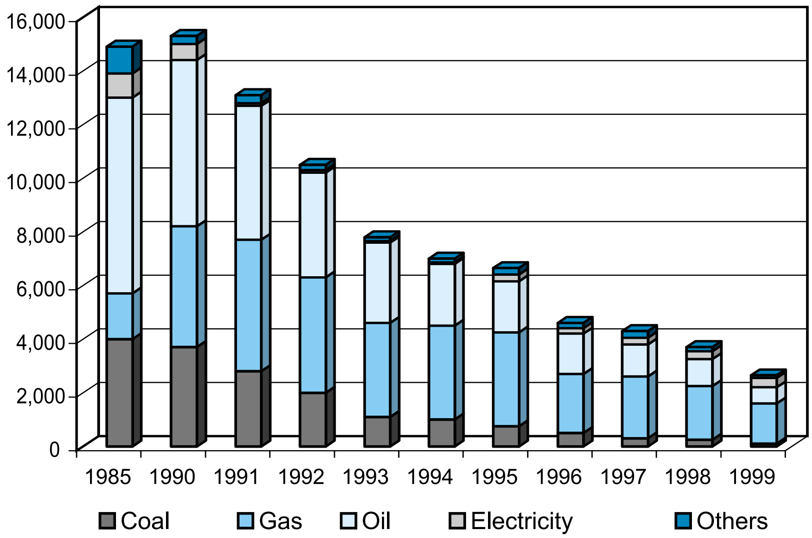


Figure 2.1. Evolution of energy resources consumption in the Republic of Moldova
Source: [1]

In the period after 1990, considerably decreased the share of the energy resources consumption in industry, agriculture and transport, while the public sector's one having been increased. The dynamics of this indicator is correlated with the rhythm of production volume decrease in the country. The energy intensity of production in RM is about 3-4 times higher than the same one in the developed countries.

There are the following energy generating power sources in the country: CHP-1 and CHP-2 Chisinau, CHP Balti and TPP Moldavian from Dnestrovsc town) and two hydroelectric power plants (Dubasari and Costesti). The installed capacity of the country's power stations constitutes about 3,000 MW, but there are used only about 1,600 MW. The available capacity of hydroelectric power plants constitutes 30 MW.

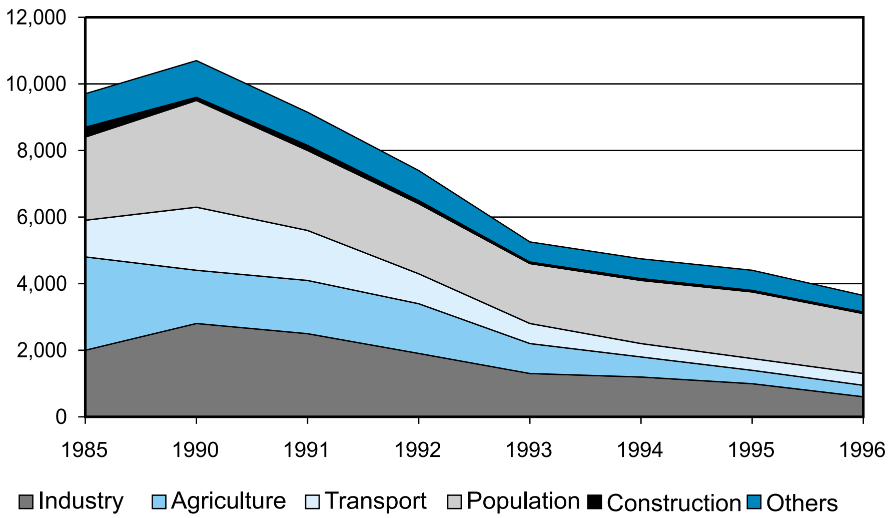


Figure 2.2. Consumption weight of energy recources in GDP

The energy production capacities have a non-uniform territorial repartition, the majority (more than 80%) being concentrated on the left side of Dnestr river. It should be mentioned that the majority of energy generating capacities have an advanced rate of wear. The insufficiency of the country's production units cause the increase of electrical energy import – up to 30-40% of the yearly total consumption. In a short term there should be repowered the existent energy generation capacities, thus the construction of new power plants optimal distributed on the country's territory it is imperious.

The country's electrification degree is 100%. The number of possible non-connected consumers to the public network is insignificant, just several dwellings situated outside the rural localities.

The total thermal energy production capacity is about 1,300 Gcal/h. The cities of Chisinau and Balti dispose of centralized heating systems. In other cities there are used district thermal plants (TPs), that didn't operate in the last two years, because of fuel lack. The national gas supply system contains: about 1,700 km high-pressure lines, over 2,000 km of medium and low pressure lines and 165 distribution stations. There are gas supplied only 25% of the total number of the country's localities. The gas pipeline Russia-Balkans is crossing the RM's territory. The supplying system of liquid fuels is totally privatized and contains a large network of petrol station and oil product deposits. The oil product terminal is at the level of construction, in the south of republic, in Giurgiulesti.

Not so long time ago, the main segments of supplying and distributing gas, the power and thermal energy, solid and liquid fuel, were represented by state structures. Since 1995, it proceeded to demonopolization and privatization of energy sector. From the total of five electricity distribution networks (EDN), three are privatized, the other two are following the same way. The CHPs will be privatized in the near future. The gas supply system was reorganized into a mixt moldo-russian company. The heating company "Termocomenergo" was reorganized as well, being subordinated to the local authorities.

As regards the legal support for energy sector , in the last years there were elaborated and adopted a set of laws and normative documents. It means by "Law on energy", "Law on electricity", "Law on gas", "Law on energy conservation".

2.2. The RM's energy strategy correlated with the problem of environment protection

The RM's strategy of socio-economical development (till 2005) [6] foresee as a principal objective the creation of necessary conditions for a 5 and 8% GDP annual growth.

The economical reform in the energy sector continues to be a priority. As strategic objectives of this reforms, there are nominated [7]:

- Finalization of restructuring and privatization of the energy sector and the creation of the energy market;
- Ensuring state energy security;
- Environmental protection.

The strategic objectives will be realized by: energy complex demonopolization; its privatization and the promotion of the competition on the energy market and that would contribute to the energy efficiency increase; the costs decrease; the implementation of efficient energy, including the utilization of RES (solar, wind energy, biogas); the diversification of ways of energy resources import; renovation and expansion of the own competitive energy production capacities; the consolidation of energy inter-connections with East and West; the development of gas supply system and the finishing of the Giurgiulesti Oil Terminal; the development of the legislative and normative frame for the energy sector; the lining up to the international standards and European environment protection norms.

The RM's energy strategy [7] contains specific figures regarding the energy sector development over the 10 years term (2000-2010) in the context of the strategical objectives of natural economy relaunch. In tab. 2.2 there are presented energy indicators for the related period, including those indicators regarding energy resources consumption.

In the next 10 years, it is expected an increase of 1.55 times of gas consumption, a 24.5% growth of oil products consumption and more than a doubling (2.25 times) of electricity consumption as comparing to 2000.

The data regarding greenhouse gas emissions which result of the producing and using of primary energy resources for the 1990-2010 period, and final overtaken from [8], are presented in tab. 2.3. comparing to the reference year (1990) the volume of per capita emissions decreased proportionally with the energy resources consumption and constituted in 2000, 29% towards 1999 year.

As regards the foreseen emissions for the 2010 year, this can be calculated with approximation, depending on the energy resources consumption and the CO_2 specific emissions for different types of fuels. According to these calculations, we can expect a volume of 8-16.5 Mt of GHG emissions of CO_2 equivalent or

Table 2.2. Basic energy and economic indicators of the Republic of Moldova till 2010 [7]

Energy and economic indicators	1998	1999	2000	2005	2010
GDP, billions MDL	12.16	11.70	11.66	15.52	19.00
Population, mil. inhabitants	3.648	3.650	3.650	3.650	3.650
Energy intensity, t.c.e./1000 MDL	0.36	0.36	0.36	0.32	0.31
Consumption of primary energy resources, total, million t.c.e., including:	4.35	4.2	4.2	5.0	6.0
1. Natural gas, million t.c.e.	2.4	2.4	2.4	3.06	3.72
2. Coal, million t.c.e.	0.4	0.4	0.4	0.44	0.49
3. Oil product, million t.c.e.	1.16	1.14	1.14	1.23	1.42
4. Electricity consumption, billion. KWh	4.4	3.5	3.5	6.0	8.3
5. Consumption of primary energy resources per capita, t.c.e./per capita	1.19	1.15	1.15	1.37	1.64
6. Consumption of electricity per capita, kWh/per capita	1,206	959	959	1,644	2,274
Note: Energy indicators are presented without taking into account the Transnistrian region.					

Table 2.3. Real and predicted direct greenhouse gas emissions for the energy sector, Gg CO_2 equivalent / year

Year	Real emissions	Year	GHG emissions, forecast		
			Base	Minimum	Maximum
1990	27,150	2000	7,750	7,672	7,669
1994	12,203	2005	9,071	8,627	7,594
1998	7,545	2010	11,134	9,660	7,794

4.52 tons per capita. The electricity consumption of 8.3 billion kWh foreseen for the 2010 year will lead to about 4.01 Mt CO_2 emissions or 1.1 tone per capita. Here, it was not specified if the electricity is imported or generated in the country, because the pollutants are stateless: they do not acknowledge any borders, attacking equally the country they were produced in and the neighbors, even the distant ones.

The volume of CO_2 emissions of the energy sector towards 2010 will not achieve the 1990 year level (6.23 tone per capita), but will be enough sufficient comparing with the fixed norms for the industrialized countries for the same period.

The described measures of environment protection, especially those regarding the energy efficiency increase and the replacing of the classical systems of fossil fuel generating energy with others, based on the utilization of RES, could contribute efficiently to the GHG emissions reduction in the energy sector, which generate about 70% of the total GHG emissions in the country.

BIBLIOGRAPHY

1. National Strategy on Sustainable Development. Economic Superior Council under the president of the Republic of Moldova, United Nations Development Program, Chisinau, 2000.
2. The Law of the Republic of Moldova on energetics, nr.1525-XIII from 19.02.98, Official Monitor of the Republic of Moldova, nr.50-51/366 from 04.06.1998.
3. The Law of the Republic of Moldova on electrical energy, nr.137-XIV from 17.09.98, Official Monitor of the Republic of Moldova, nr.111-113/681 from 17.12.1998.
4. The Law of the Republic of Moldova on the conception of the privatization of enterprises from the electro-energetic sector, nr.63-XIV from 25.06.98, Official Monitor of the Republic of Moldova, nr.77-78/523 from 20.08.1998.
5. The Law of the Republic of Moldova on energy conservation, nr.1136-XIV from 13.07.2000, Official Monitor of the Republic of Moldova, nr.157-159/1183 from 12.12.2000.
6. Short-term economic development strategy of the Republic of Moldova (till the year 2005), project, Chisinau, 2000.
7. Decision of the Government of the Republic of Moldova on the approval of the Energetic Strategy of the RM till 2010, nr.360 from 11.04.2000, Official Monitor of the Republic of Moldova, nr.42-44/443 from 20.04.2000.
8. First National Communication of the Republic of Moldova elaborated within the framework of the United Nations Convention on Climate Change, Republic of Moldova, Ministry of Environment and Territorial Arrangement, Chisinau, 2000.

3. THE ASSESSMENT OF TECHNOLOGICAL, ECONOMIC AND ENVIRONMENTAL NEEDS REGARDING THE IMPLEMENTATION OF RENEWABLE ENERGY SOURCES (wind, solar and biomass) IN THE REPUBLIC OF MOLDOVA

3.1. Feasibility study regarding the implementation of wind energy in the Republic of Moldova

3.1.1. Methodological aspects of assessment

Often, in different environments the existence of favorable and profitable wind energy potential appears as doubtful for its exploitation in the RM. At the same time, the multiple scientific researches performed in different periods, as well as the achievements obtained on the sites have proved that on the territory of RM there are enough zones with favorable winds for efficient operation of the wind installations. Thus, in order to motivate the efficiency or inefficiency of wind energy utilization, it's sufficient to know the annual value of the energy that could be generated by a wind turbine in some concrete points of the investigated zone. Saying in other words, we should know the **wind energy cadastre** of the investigated territory.

The foundation of a project of implementing the wind energy installations first of all requires a detailed knowledge on wind energy parameters of the future location zone and particularly the wind velocity probabilistic distribution, diurnal and seasonal speed variation, prevalent directions and other parameters.

The wind energy is proportional to the wind speed cube in the zone of installation emplacement. In order to obtain statistical data of a high level of credibility, there are necessary systematic long term observations, as the leaders experience in wind energy domain proves it. But in this case, appears a complicated problem: data which result from long term observations, performed by the meteorological stations of neighborhood, cannot be automatically extrapolated on the new emplacement, because the wind parameters measurements carried out by the meteorological stations at a 10-12 m height, are strongly influenced by the relief form and by the rugosity of the environing territory.

From these reasons, there are necessary complex techniques, entirely special, that would consider the influence of the set of climatic and orographic factors at wind speed formation in a given geographical point.

3.1.1.1. Assessment models and programs

At present there are used two models in order to evaluate the wind energy potential. The model elaborated by the EU countries [1], known as WAsP (Wind Atlas Analysis and Application Program) – which served as a basis for review of wind energy potential and for drawing up the **European Wind Atlas**

[2], that relies on the air currents theory. The stipulated model requires enormous database on wind speed history for a period of minimum 10 years (these could be obtained from the meteorological stations) and data regarding characteristics of the meteorological station territory and of the place where the wind energy unit (air-generator) will be laid out. The American model elaborated by NASA and U.S.A. Air Forces, relies on the dynamic climate theory and requires few data, but it needs a high computer processing power.

The high WAsP program efficiency has determined several Central European States (Austria, Croatia, Slovenia, Czechia and Slovakia) to use it for drawing up their own wind atlases similar to the European one.

For this purpose, there were performed important researches in Romania and the Ukraine – countries in which operate several wind farms, with the power of installations about 5-10 MW.

WAsP is a computerized program for the bidimensional extrapolation of the wind measured parameters, taking into account the description of the territory and neighborhood obstacles of the meteorological station. It contains 4 basic counting modulus:

❑ **Analysis of "gross" measured data.** The respective option allow the analysis of statistical – meteorological wind data, measured at the meteorological stations. This modulus is viewed as a separate WAsP tool.

❑ **Elaborating wind atlas.** The analysis indexes are converted into a data set, that represent the wind atlas. The atlas data set are related to the specific conditions of the meteorological station location and at the same time are recalculated for standard – conditions (five heights and four classes of rugosity).

❑ **Wind climatological estimation.** Using the atlas data, calculated with the WAsP program support, we can estimate the wind value in any far-off emplacement, underlining the possible emplacements. The modulus permit the estimation of the wind real value in the interested emplacement.

❑ **Estimation of wind energy potential.** With this modulus is calculated the wind energy potential depending on its annual average value. Alongside with the estimation of the wind energy power, WAsP allow to estimate the annual energy production, for any given air-generator.

3.1.1.2. Techniques of processing data regarding the periodical records of wind speed and direction

WAsP program can be used for the subsequent evaluations, in two purposes:

1. The analysis of wind primary data with a view to elaborating the wind atlas for each meteorological station
2. The utilization of the wind atlas and air-generator power curves with a view to assessing wind and energy potential in any neighborhood station point (on a radius of 50 km).

The WAsP program is structured in such a way, that the hierarchical elements (firstly the primary data) contain specific information: speed and wind direction, the orography of the territory, as well as the forecasting climate (wind) and energy instruments that could be obtained. Respecting the hierarchy of the constitutive elements enable the formation of some logical liaison between them, that would describe the studied territory, meaning the territory intended to modeling.

A) Meteorological data and the station description. The description of the meteorological station includes: data on the station's latitude and longitude, the height at which were effected the measurements. The primary meteorological data include information on the direction and the wind average velocity, measured each three hours for a 10 years period. Relying on the primary data, WAsP program will calculate the wind-rose and Weibull distribution parameters of wind velocity repeatability. In figure 3.1 there is represented an example, calculated for a meteorological station, situated in the south of the republic. These gross data (unprocessed) characterize only the observation point – the meteorological station. Here and as follows it will be utilized the RM's State Hydrometeorology Service data base [5].

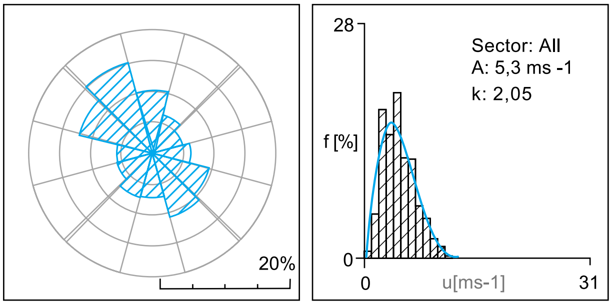


Figure 3.1. Wind-rose and Weibull distribution of wind velocity repeatability. For measurements effected during the last 10 years in the south of the country

In order to extrapolate the climatological wind values and to describe more exactly the station and its surroundings, it should be taken into account the influence of proximity obstacles, rugosity degree, as well as the orography of the territory around the observation point. These data can be used in order to estimate wind indexes in other locations nearly the meteorological station, only after their processing.

Table 3.1 present for the same station (figure 3.1.) the repetition rate, the weight of different wind velocities, as well as the Weibull coefficients for those 12 sectors, each of 30°. From this table, it can be observed that the prevalent wind velocity, measured at a 10 m height during 1990-1999 period, was contained between 3-7 m/s – velocity at which no modern air-generator can operate. But it should be mentioned that the given results were influenced (diminished) by the obstacles and rugosities from the meteorological station perimeter. In the subsequent calculations, WAsP will consider all those primary data, thus modeling the real situation.

We specify that the validity of the statistical data of a concrete station depends on the data veracity and on the volume of available information.

B) Obstacles. There is presented an obstacles list of the meteorological station neighborhood or air-generator, which could affect wind characteristics of this locality. As obstacles there are considered the buildings, the walls, the doors, trees strip or bushes, each of them being characterized in the list by a climatologic

Table 3.1. Analysis results, measurements at the meteorological station, in conformity with WAsP

Sector, (°)	Frequency, %	Weighted wind velocity per sector, %													Weibull coeff.	
		<1	2	3	4	5	6	7	8	9	10	11	12	13	A	k
0	9.66	1	5	18	16	23	13	12	5	4	2	1	0	0	5.1	2.16
30	6.51	1	6	16	16	21	13	11	7	5	2	1	1	0	5.3	1.98
60	4.39	2	4	13	14	22	11	14	6	7	3	2	1	1	5.5	2.07
90	5.68	1	5	12	11	19	15	14	8	6	4	3	1	1	6.0	2.25
120	9.17	1	2	10	11	18	14	16	10	8	5	3	1	1	6.4	2.55
150	10.28	1	3	10	11	19	13	15	11	9	4	3	1	0	6.4	2.61
180	6.70	1	7	17	14	20	12	15	6	5	2	1	0	0	5.2	2.30
210	7.02	1	9	24	20	22	11	6	3	2	1	1	0	0	4.4	2.16
240	6.26	1	10	25	20	21	10	7	2	2	1	1	0	0	4.3	2.17
270	6.21	1	10	29	18	17	9	8	4	2	1	1	0	0	4.4	1.91
300	12.46	1	6	23	16	18	12	11	5	5	2	1	0	0	5.1	1.95
330	15.67	1	4	17	16	20	13	12	7	5	2	2	1	0	5.4	2.07
Total	***100***	***1***	***5***	***18***	***15***	***20***	***13***	***12***	***6***	***5***	***2***	***2***	***1***	***0***	***5.3***	***2.05***

coefficient, called porosity. The porosity describes the degree of retaining the wind by an obstacle and depends on its density.

As a general rule, porosity can have a null value for buildings and approximately 0.5 for trees. A range of similar houses, separated by a distance equal to a third of a house length, will have a porosity of about 0.33. The trees porosity changes together with the foliage, namely depending on the season. Alike the rugosity degree (described further on), porosity should be considered a seasonal climatological parameter.

For example figure 3.2, contains the graphical presentation of obstacles situated in the neighborhood of a meteorological station. The porosity degree of the obstacle is reflected by the color intensity of the respective symbol.

The obstacles attenuate to a certain extent the wind velocity, measured by an anemometer at the meteorological station.

The influence degree (diminution) exerted on the measured wind values, depends on:

- the distance from the obstacle to the emplacement;
- obstacle height;
- emplacement height;
- obstacle length.

The importance of including the obstacles in the evaluation model is illustrated by the curves presented in figure 3.3, which reflects variations of wind average velocity and available power depending on air-generator height – for the same location – with and without obstacles.

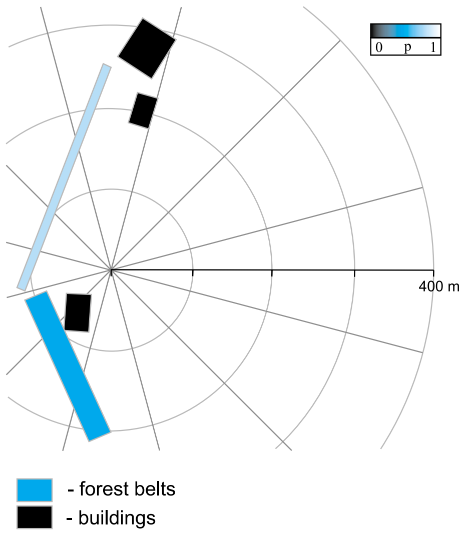


Figure 3.2. Graphical representation of obstacles in the neighborhood of the meteorological stations

It can be observed that for the usual heights of fitting the air-generator (60-70 m), the difference of the specific power, which could be obtained when removing obstacles, is about 100 W/m^2 (10-15%).

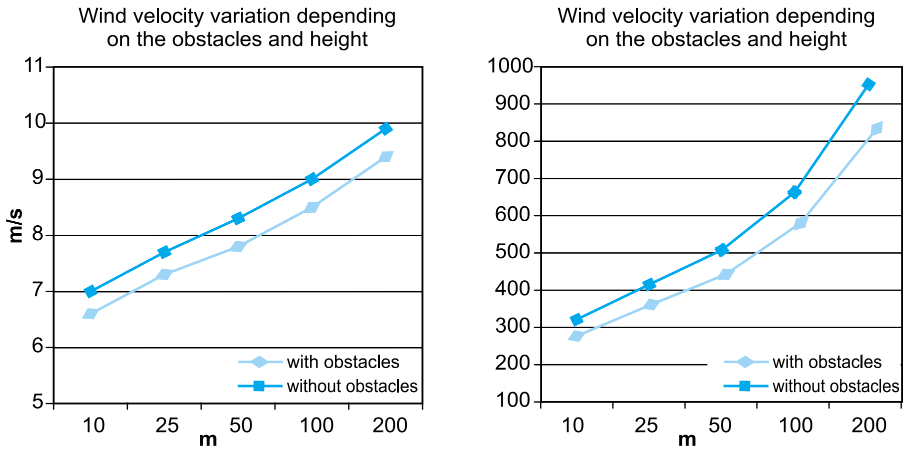


Figure 3.3. Obstacles influence in evaluating the wind energy potential

C) Rugosities. The rugosity of an area is determined by the size and the distribution of its elements. The rugosity element is characterized by its height and gross-section. Moreover, for a number of elements uniformly distributed on a field, the density can be described as the average of horizontal area, available for the element.

The ground characteristic is in general paramultiphased by a measure scale, called roughness coefficient and is utilized for describing the type of the relief around the meteorological station of air-generators. In the wind atlas, rugosities, are classified in four important classes, which contain a large range of types of surfaces, beginning with the maritime surface (of water or maritime basin), grassland, cereal field and large areas covered by shrub's, up to cities or woods, that have the highest roughness coefficient.

The energy air-generators output should be determined relying on climatology, because the daily and seasonal variations in the specified zone can also have a deep influence.

It's mentioned that in general the roughness coefficient applied in the atlas is considered a climatologic parameter, because the surface rugosity is changing together with the foliage, vegetation, snowfalling, etc.

Comparing to obstacles, which as a rule are limited on a 500 m radius, rugosities overrun much more extensive territories, radius of which can achieve 5,000-10,000 m.

D) Orographic territory description. Serves for representing the ground relief on which there are placed the meteorological station and/or the air-generator: WAsP uses the map representation in a vectorial form, in which the areas are rendered by contour lines, each of it having their own identification parameters.

3.1.2. The estimation of wind energy potential in the RM

3.1.2.1. Case history regarding wind energy utilization in the RM

The Republic of Moldova has such a geographical background that its territory can be appreciated as a favorable wind zone for wind energy development. In order to build a well motivated answer it is necessary a much more detailed analysis.

Statistical data show that before the large utilization of steam engine and internal-combustion engine, the windmills were spread all over ex-government Basarabia, that holded the whole territory of present RM, county of Hotin, Akkerman and Ismail. In 1901 there were registered 6,208 windmills, distributed by countries in the following way: Balti – 299, Chisinau – 980, Tighina – 907, Soroca – 371, Orhei – 626, Akkerman – 1,304, Ismail – 1,393 etc. [6].

In 1923, Regional statistics general authority of Chisinau evaluates, in a special edition, the economic potential of Basarabia's villages. This publication offers us extremely important data regarding windmills exploitation and their territorial repartition. Thus, it was stated that some communes had over 30 windmills. For example, in the central zone there have been praised Costesti – 23 mills, Buteni – 16 mills, Vazaresti – 28, Truseni – 23, Scoreni – 17 mills; in the south zone : Talmaza – 15, Cubei – 31, Taraclia – 31, Traianul Nou – 34, Congaz – 30 and Isarlia – 20 mills.

The majeurity of pyramidal mills, were stringing in chain over knobs and tops of hills, places that were often called "The Mill Hill". A lot of those mills have been operating during the inter-war period.

During the '50 of the past century, in the country were rigged up over 350 mechanical wind installation, exclusively destined to pump the water supply system and to prepare fodders at the collective agricultural farmsteads. Those were air-motors, with many blades blades, rated at 6.2 horse-power, at the estimated wind speed of 8 m/s. They have been operating enough efficiently for a period of 7-10 years, being gradually replaced, after 1960-1964, by electrical systems more comfortable and more cheap in exploitation. The total electrification, that occurred in this period, as well as the very low level prices for electrical energy bring out the wind energy.

There also should be mentioned that the negative appreciations, that appeared in the profession literature at the beginning of '90s of the past century, regarding wind energy utilization in the RM, were made in the hurry without any serious motivation.

These affirmations were based on the data regarding the annual average wind velocity, determined for Chisinau Meteorological Station, which being surrounded by a multitude of obstacles, cannot at all be considered as a reference station. The researches performed on the job, proved that the some more meteorological stations of republic do not suit the standard – conditions regarding the measurement of wind velocity.

As follows, we will make an motivated revaluation of this domain, using new data regarding wind velocity and the most recent methodologies of analysis, as well as the technical characteristics of last generation wind aggregates.

3.1.2.2. Wind energy cadastre of the RM

A) Wind Atlas. The wind atlas goal is to present data on wind energy resources in a certain zone (methodological station), as well as the supply of methodologies in order to generalize the related data in the environing region. It is meant to estimate the wind energy potential and to identify the best places for wind farms emplacement.

The wind atlas contains, as basic information wind climatic data (local or regional) obtained as a result of measurements at the meteorological or other similar stations and adjusted for their evaluation by WAsP program.

After effecting calculations, there is obtaining the wind atlas (figure 3.4), which contains average wind velocities, specific capacities for five fated heights (10, 25, 50, 100 and 200) and for those four classes of rugosity related to the standard – conditions. Along side with this tabular data, there is obtained also the wind rose and the Weibull distribution parameters, both being recalculated in conformity with to meteorological primary data (figure 3.1). There should be mentioned that each atlas describes the wind and energy conditions, which refer to a certain point – to the station, where the measurements were effected. On the basis of this data, there will be counted the same characteristics for any wished location of the neighborhood, by extrapolation, on a 50 km radius.

		R-class 0 (0,000 m)	R-class 1 (0,030 m)	R-class 2 (0,100 m)	R-class 3 (0,400 m)
Height 1 (z = 10 m)	ms-1 Wm-2	7,0 322	4,8 125	4,3 83	3,4 40
Height 2 (z = 25 m)	ms-1 Wm-2	7,6 414	5,8 201	5,2 148	4,4 88
Height 3 (z = 50 m)	ms-1 Wm-2	8,2 505	6,7 286	6,2 221	5,3 145
Height 4 (z = 100 m)	ms-1 Wm-2	8,9 658	8,0 460	7,3 352	6,4 235
Height 5 (z = 200 m)	ms-1 Wm-2	9,8 922	9,9 911	9,0 680	7,9 439

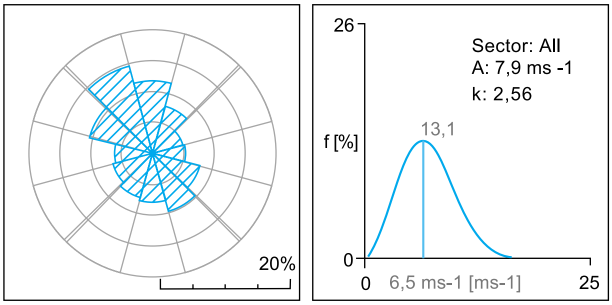
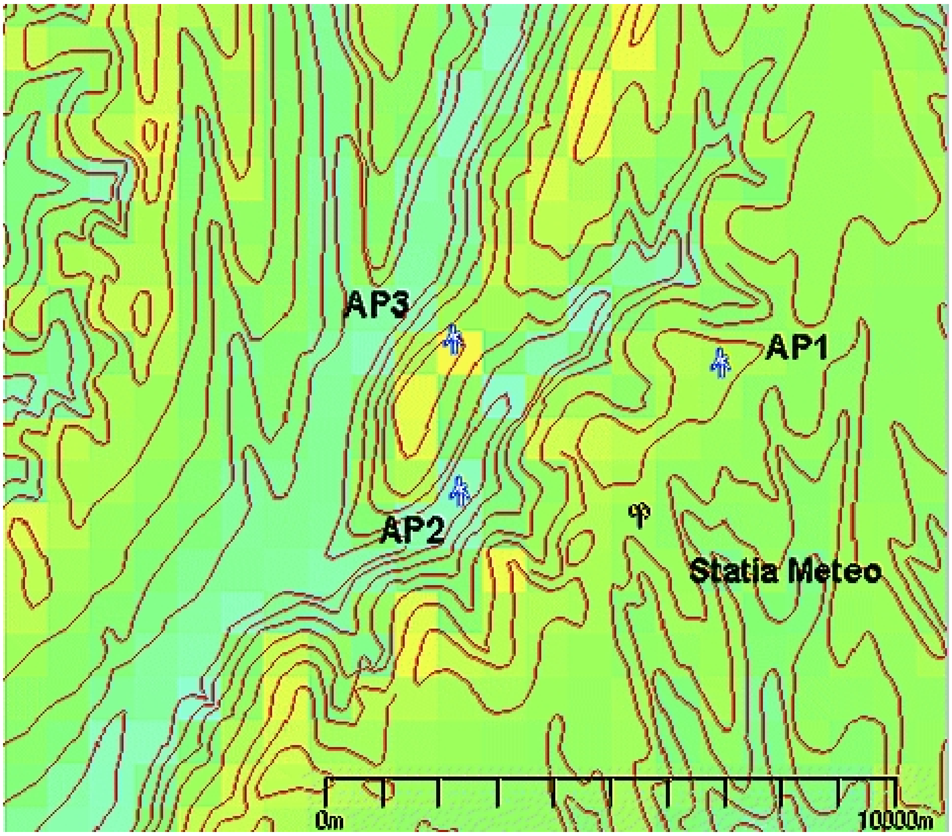


Figure 3.4. Wind Atlas

B) Wind resources map. The wind resources map reproduces the variation of wind–energy resources above any expanded and relatively homogeneous areas. This map contains the final climatological and energetic wind values for any terrestrial surface, the atlas data being extrapolated and adjusted to the orography of the analyzed territory. Moreover, the wind resources map can also supply data (maps) regarding the territory orography, Weibull coefficients, the available power and the energy that could be obtained.

The map in the figure 3.5 describes the wind resources from the surroundings of a meteorological station.For wind potential analysis there was choused a representative area in the South of the country (with a maximal altitude of 200m). in



	10 m		25 m		50 m		100 m		200 m	
	m/s	W/m²	m/s	W/m²	m/s	W/m²	m/s	W/m²	m/s	W/m²
yellow	5,35	171,3	6,18	246,1	7,02	330,5	8,20	503,3	10,01	941,0
green	4,92	131,1	5,84	205,7	6,72	287,1	7,94	454,6	9,83	887,3
blue	3,99	72,0	5,00	130,3	5,94	198,9	7,21	341,1	9,17	720,5

Figure 3.5. The map of wind energy resources for a representative territory in the southern part of the Republic of Moldova

the adjoining table there are indicated specific available capacities (W/m^2), calculated for the standard-heights. A wind resources map, similar to that of figure 3.5, can be performed for any territory. With a smaller degree of precision (because not all the meteorological stations benefited of measurements regarding the rugosities and obstacles), there was elaborated the wind energy potential map of the RM (*figure 3.6*) at the height of 70 m from the soil. Even if some data (measurements of the State Hidrometeorological Service) were extrapolated at the rugosities and medium obstacles of the known stations, the map represented in figure 3.6 can serve as a reference one, for making evident and estimating the future emplacements, and by the following measures, there will be possible to determine the wind potential with a high degree of precision in any installed point.

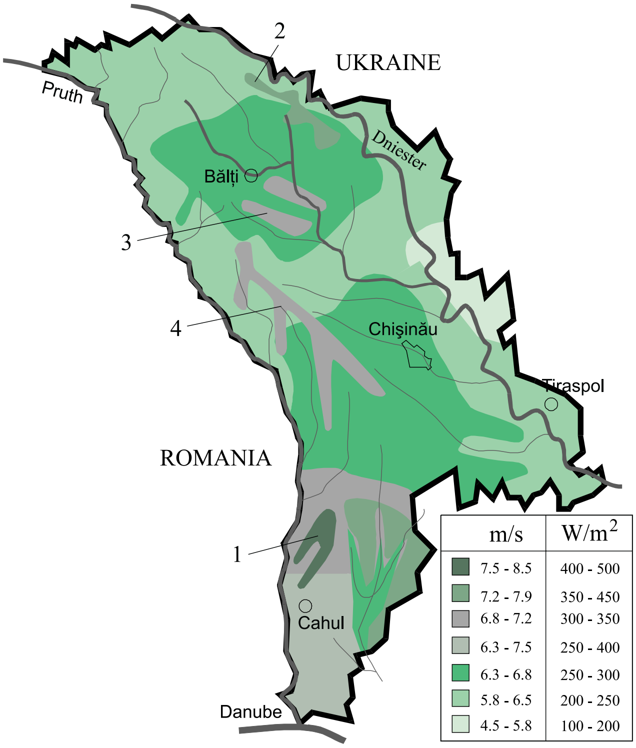


Figure 3.6. The map of the wind energy potential of the Republic of Moldova, at a height of 70 m above the ground

C) Energy estimations. The regional evaluation of wind energy resources means evaluation of the energy potential of a significant number of wind turbines present in a certain region, in this case being necessary performant computers. The related investigations can be effected at different levels of complexity. Considering an ideal case, an evaluation should be based on detailed description of the emplacement, thus being effected a large number of specific investigations on the ground.

The electrical energy, generated by an air-generator is proportional to the cube of wind velocity, which operates in a perpendicular direction on the surface scavenged by the wind turbine rotor. This way of using the wind velocity depending on the tower height, serves as a reference for appreciating the aerogenerator's capacity curve.

The power curves are utilized for wind aerogenerator's description, containing information on the conversion wind energy into electrical power. For example, in figure 3.7, there is presented such a capacity curve for the DeWindD4 generator, with rotor's diameter of 48 m and the installed capacity of 600 kW – one of the most performant air-generator in the RM's wind conditions.

Knowing the wind resources map, we can easily determine the potential emplacements, the most successfully areas for aerogenerators installations. Once decided on the wind generator type, we can estimate that the average wind velocity, the annual power and the electrical energy, that can be obtained in a certain place.

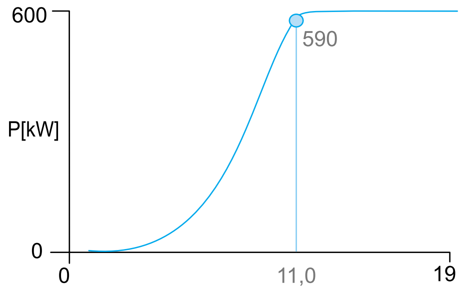


Figure 3.7. Capacity curve of DeWind D4 wind generator

Each location contains geographical coordinates, the location height, climate prognosis instrument and the capacity curve of the exploited wind generator.

For the next evaluations, there were choused three locations presented in figure 3.5 and noted with AP1, AP2, AP3, where:

AP1 – location with a medium wind potential
AP2 – location with low potential
AP3 – location with high potential

The calculations were performed using the energy characteristics of DeWindD4/ 48,600 kW air-generator, placed at a 70 m altitude. In table 3.2 there are presented evaluation results performed for those three emplacements.

Table 3.2. Evaluations for three locations with air-generators of DeWind D4 type

Emplacement	Velocity m/s	Capacity W/m²	Energy MWh/an	Weibull coefficients	
				A	K
AP1	7.31	362.04	2,062.10	8.2	2.66
AP2	6.55	261.07	1,608.14	7.4	2.65
AP3	7.60	409.01	2,226.44	8.6	2.63

It is known that the majority producing air-generator firms, among which DeWind D4, accept the modification of the heights of the air-generator tower in a larger interval, than the installed one. For example, for the analyzed air-generator DeWind D4/48 600 kW – the height limit – values constitutes 50-100 m. As a conclusive example, in the figure 3.8 is presented the dependency of an annual generated electrical energy by the DeWind D4 air-generator on the tower height, for the AP1, AP2 and AP3 emplacement.

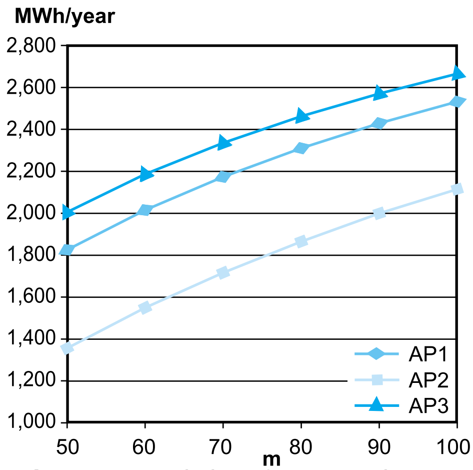


Figure 3.8. Variation of generated energy by DeWindD4 air-generator during a year, depending on the tower height

The difference between the energy obtained in the case of the 50 m tower and that of 100 m, is about 700 MWh/year. The tower's cost varies between 700 and 1,000 Euro/m. Thus, at a 0.05 Euro/kWh electrical energy price, the additional cost of the 100 m tower towards the 50 m one, will be retrieved in a period of up to 1.5 years.

3.1.3. Technological aspects regarding wind energy installations implementation in the Republic of Moldova

3.1.3.1. General aspects

The wind installations can be classified in two categories: mechanical installations and air-generators, depending on the usage mode of the obtained energy as a result of wind energy conversion. In the first case, the energy is used exclusively for producing a mechanic work, while the air-generator's installations transforms the mechanical energy into electrical energy, so that it could be easily transported at any distance and used in the most rational way.

The utilization of wind installations for generating energy is the most effective way of exploiting wind energy, due to the fact that the conversion process efficiency of mechanical power into electrical one constitutes about 90-95 %, and the losses of the transport line to the exploitation place usually do not overrun 10 %.

Direct-current generators, synchronous or asynchronous generators can complete the air-generator installations.

Direct-current generators are utilized only in the low capacity installations, for charging the accumulator battery.

The synchronous generators with excitation of permanent magnets are used for considerable capacities; they have the efficiency and the capacity factor enough high, but their utilization is limited by problems of synchronizing the generator in the process of its connection to the network.

The asynchronous generators are suitable for high capacities. The simple construction of this electrical machine assures to it a high reliability, a relative low cost, minimal maintenance expenses. The specific electromechanical feature of the asynchronous generator assures an increased stability in conditions of variable deflecting torque and considerable load variation. As well, there are no problems of excitation and synchronizing in the alternating current network with constant parameters. Reactive energy consumed by the generator for operating, is usually compensated, using condenser batteries.

The air-generator installation structure and the type of produced energy quality control depend to a great extent on the requirements imposed by the electrical energy consumers. These requirements can be enough tough, in the case of electric engine, lightning, electronic equipment and less strict, in the case of using the energy for heating.

The choice of air-generator installation structure and the energy quality controller, should also consider the settlement of the following specific problems:

- the optimization of the generator operation regime, in circumstances of permanent wind velocity variations;
- the compatibility assurance of the airengine and electrogenerator operating parameters;
- the synchronizing of electroengine's parameters with the electrical network ones, in case of their joint operation;
- formation of power reserves for calm weather periods, necessary reserves for consumers that can't afford deenergizings;
- optimization of cheep energy consumption, but less qualitative, generated by the aerogenerator.

There are illustrated three cases of using aerogenerator installations, within which the above mentioned problems are installed differently:

- autonomous system, in which the air-generator installation (one or more) cover entirely the electrical energy consumption;
- combined autonomous system – concomitant with the wind station, deliver to the common network energy and other electro generator power sources, comparable to the air-generator ones.
- Wind stations, as a rule with several aerogenerator installations, which deliver energy to the public network of an incomparable higher capacity.

3.1.3.2. Installations and autonomous stations

The destination of these systems can be: electrical lightning; energy supply of lamps, of means of telecommunications, with a total power of up to several kilowatts, of other consumers that are not comprised by the public electrical network. Autonomous installations can be also useful in the electrified zones, being used as cheep energy sources for heating.

The operating efficiency of wind energy installations, its cost, depend to a great extent on the type of the utilized system for the speed control of and on the shaft power.

In case of a minimal exerted order on the generator, if it's of alternating current, the frequency and the terminal voltage (at the consumer) will be unstable. Considering the quality of the indexes, the related energy can be exclusively used for heating. For other goals, the electrical energy obtained from the air-generator is rectifying with a simultaneous parameters stabilization (*figure 3.9, a*). In many cases such an installation can be sufficient. The minimal qualitative energy requirement of alternating current with stabilized parameters can be covered by using a inverter energized from the accumulator battery, which operates in a floating way. The accumulator's capacity will be determined beginning with the energy demand for the specified consumers, in a calm weather period, with a maximal duration in the related period.

The quantity of transformed energy will be limited only by the admissible cost of accumulator battery and inverter. If the pretentious consumers can be supplied exclusively with continuous current, the supply system will include only the aerogenerator, the rectifier, the accumulator battery and the control system.

In case if all the generated energy by the aerogenerator must suit a certain frequency, there are two variants of its stabilization:

- the stabilization of aeromotor relative speed, using the modification of the blade's angle of attack (*figure 3.9, b*), depending on the installations value of wind velocity. Control system' s disadvantage is: a significant part of wind energy is not exploited, the control system is complicated and low reliable;
- the stabilization of aeromotor relative speed by electrical means. With a view to this, the generator's shaft is regulating, being permanently conformed with the available capacity (*figure 3.9, c*). The follow-up and control system uses as primary information the signals of the wind speed transducer and aeromotor rotative speed. Being provided with modern electrical equipment, these systems become more efficient and high reliable at a less cost comparing to mechanical control system.

The wind autonomous installation can be endowed with electrical generators of continuous current with permanent magnets and special devices to equalize current and voltage pulsations. The generated energy is utilized for charging accumulator batteries. More often there are used synchronous

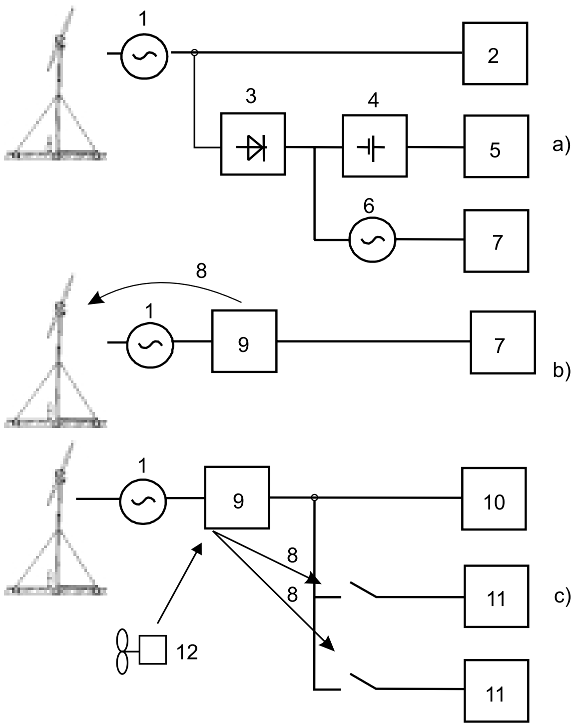


Figure 3.9. Variants of autonomous wind energy systems:

a) – without stabilization;
b) – with mechanical regulator;
c) – with load regulator

1 – electro generator; 2 – electrical heating installations; 3 – rectifier; 4 – accumulating battery; 5 – consumers of continuous current with stabilized voltage; 6 – autonomous inverter; 7 – consumers of alternating current with stabilized parameters; 8 – reaction loop; 9 – controller/ regulator; 10 – priority consumers; 11 – secondary consumers; 12 – anemometer.

generators with permanent magnets or with self-excitator and with a feedback loop on the load current used for stabilizing the voltage at the generator's terminals.

Air-generator can be a component part of a local energy system. Air-generator's capacity is of the same level as of other local generators which in turn can represent Diesel generators, photovoltaic cells units, biogas cogeneration units (*figure 3.10*).

The usage of wind installations afford in these cases, to save fuel. The Diesel-generator will operate only during the calm weather periods in parallel with the air-generator, thus compensating the energy deficit in each moment.

There also should be mentioned the fact that, because of the high cost of control and energy storage systems autonomous systems, require considerable initial capital investments (*table 3.4*). As follows, the obtained electrical energy price will be also high. The utilization of these systems can be justified only in special cases.

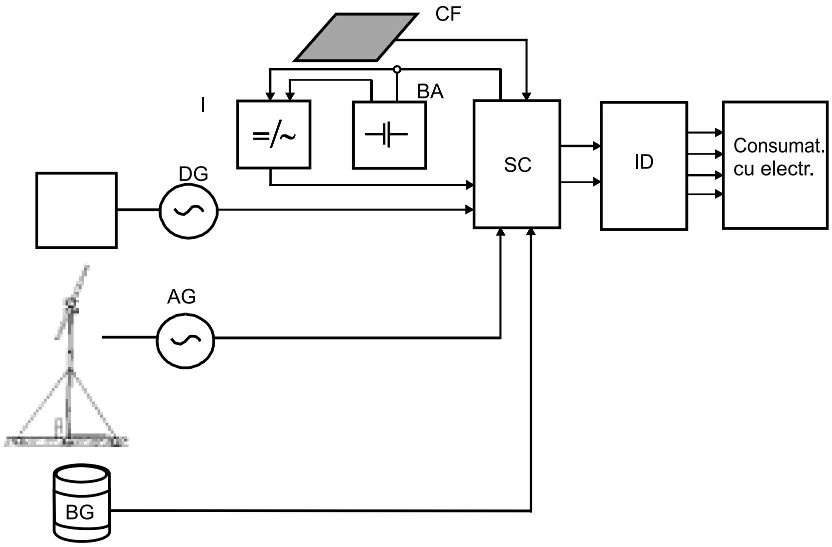


Figure 3.10. Complex local energy system feeding an agriculture farm:

AG – air-generator; DG – Diesel generator; BG – Biogas installation; CF – Photovoltaic cells; I – Inverter; BA – Accumulating battery; ID – Device of distribution of electrical energy; SC – control system.

3.1.3.3. Air-generator stations connected to the public electrical network

Several air-generator's, in group of 30-50 units form a wind energy power plant (WEP) which by the means of one or several voltage step up are connected to the public network of electrical energy feeding of a considerable power comparing to the total wind installation power (*figure 3.11*).

This way of using the wind energy is the most spread in zones with favorable wind conditions and in which there are public electricity systems. The entire

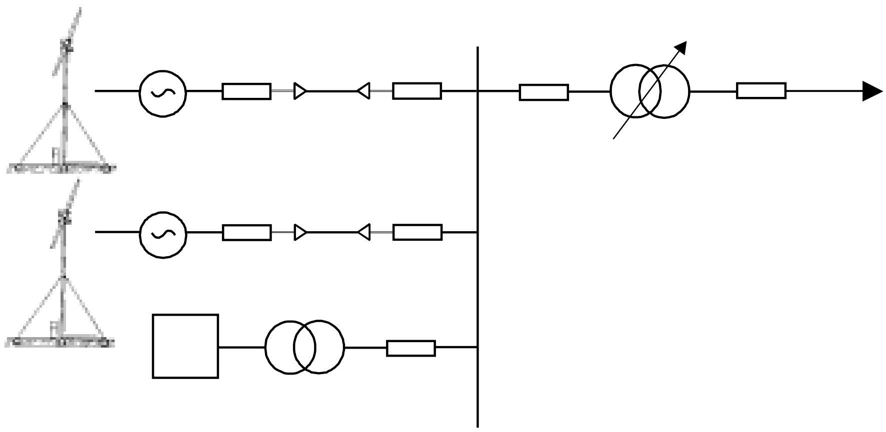


Figure 3.11. Diagram of WEP connections

1 – aerogenerator; 2, 3, 4, 6, 7 – automatic circuit breaker; 5 – transformator 10/35 kV or 0,6/10kV; 8 – transformator 10/0,4 kV; 9 – consumes.

volume of electricity produced by WEP is delivered to the public system on a commercial basis. The WEP own consumers are also connected to the public network, their consumption being countered.

In these terms, the most suited are installations with asynchronous generators – due to the high reliability, minimal cost and maintenance expenses. At the same time, the synchronization problem is being solved automatically. The stabilized level of the voltage and frequency at the generators terminals is imposed and maintained only by the network, without any control system intervention. The regulating system intervenes only with signals of disconnecting the generator of the network when the wind velocity is too insignificant and the aerogenerator could operate in ventilation condition, with network energy consumption.

The generator's practical constant rotative velocity, imposed by the frequency in the network, will condition an airengine operating in a not at always optimal regime. In these case, there can be of use the following assurance modalities of an optimal regime of energy conversion in the aeromotor :

- it is utilized an asynchronous generator, with a number of pair of poles which is regulated in steps, depending on the momentary wind velocity;
- the airengine operates with a variable optimal rotative speed depending on the momentary wind velocity, but the obtained energy of a synchronous generator with permanent magnets (with an unstabilized frequency and voltage) are rectifying, then is transforming into alternative current with stabilized parameters, using an inverter commanded by the network. The turbine rotative velocity is regulated depending on the wind velocity, modifying the inverter's charge (the power injected in the network).

A prospect variant represent the asynchronous generator installations with axial entrefer and disk rotor, whose nominal low speed conforms favorable with airengine's speed, keeping at the same time all the classic asynchronous generators' advantages [7].

3.1.3.4. Wind installation for pumping

As to the chronological point of view, the oldest are considered the mechanical installations, widely used in the past centuries to put into action the mill-stones and the pumps in the water supply, irrigating and draining systems. And nowadays, ten thousands of small wind installations of pumping are effectively used especially in the farmers husbandries. A water storage basin solves the problem of reserving, during the calm weather and low wind velocity periods. These installations are endowed usually with piston pump or Vergnet pumps, being drove by the airengine's shaft by the means of a rod.

For an efficient utilization of wind energy on a large range of speed in these installations there are used aerengine's (turbines) with many blades, which starting with lower wind velocities, develops a great deflecting torque , sufficient for pump's operation. Together with the wind velocity, increases and the number of airengine rotative speed, that assures a proportional growth of the pump debit at a practical constant pressure.

The wind conditions on the territory of the Republic of Moldova, are favorable for using wind pumping installations either for water supplying the cow farms, or for irrigating the gardens.

A disadvantage of the wind mechanical plant represents the complicated transmission and its intensive wear. Moreover, the efficient usage of mechanical installations, for example for pumping, suppose the existence in the same place both the water source and the favorable wind conditions, that does not take place always.

3.1.3.5. Producing firms and costs

The global industry, especially the European and the U.S.A. one, brought wind energy market air-generators and air-turbines, which contain a large range of capacities, constructive concepts, and solutions of completing as it is possible, of which the user could choose the optimal variant for specific weather conditions, depending on the destination [8, 9, 10].

In table 3.3, there are presented several data regarding the firms producing air-generators for terrestrial wind farms and off-shore injecting the produced electricity into the public network.

Dissecting the air-generators' market on capacity segments, we will state the features of each series of installations. Thus, the Spanish firms Mode and Desarollos dominate the segment of installations until 500 kW. The NEG-Micon dominates the 500-999 kW segment, which at the moment is prevalent among the existing installation in the world. Finally, the Enercon and the Nordex share the leader position on the segment of wind power installations more than 1 MW. At the moment the 2.5 MW class air-generator with the rotor's diameter of 80 m is consider the most powerfull one.

Table 3.3. Producing firms of large air-generators

Firm	Country	Range of capacity, kW	Specific price Euro/kW	MW sold in 1999	Sales in 1999
NEG-Micon	Den.	600, 750, 1500, 2000	855-1,092	761	631
Vestas	Den.	500, 600, 1,500, 1,650, 1,800	–	652	483
Bonus	Den.	150, 300, 450	–	338	222
Nordex	Den./Germ.	250-600, 1,000, 1,300, 2,500	930-1,178	306	150
Enercon	Germ.	200, 5,000, 600, 1,000, 1,500, 1,800	926-1,213	488	406
DeWind	Germ.	500, 600, 1000, 1,250, 2,000	850-1,118	58	38
Enron Wind Corp.	USA	300, 600, 750, 900, 1,500*	430-1,020	360	–
Gamesa	Span.	≤500	1,110-1,236	494	344
Mode	Span.	<500	–	218	–
Ecotechnica	Span.	<500	–		
WidWorld	Germ.	250, 500, 600, 750	–		
SEEWIND	Swed.	110, 750, 600, 750, 1,500	830-1,075		
Wind Energy		300, 600, 1,000, 1,300, 2,000	860-1,120		
Wincon	Den.	600, 755	813		
Fuhrlander		250, 800, 1,000	817-982		
Jacobs Energie		600. 750. 1,050. 1,500			

Den.- Denmark, Germ. - Germany, Span. - Spain, USA - United States of America, Swed. - Sweden
* – H_{turn}=80-100 m

There was stated that in 1999 the sales generated by the engineering air-generators industry has achieved the level of 2.7 billions of Euro.

Concomitant with the wind installations market of megawatt order, there is developing very dynamic the market of small capacities installation, destined for electrical autonomous systems: for lightening, desalting, refrigeration; petroleum pump; water feeding and irrigating pumps; for telecommunications (*table 3.4*). Connected to the terminals of the accumulating batteries, they meet reliably the individual electricity demand of the isolated consumers.

For the houses unconnected to the network, on the market can be found air-generators of less that 1kW till 10 kW, which can cover the electricity necessary of till several thousands of kW per year. These installations are proposed in couple with an accumulator battery and a load regulator, successfully replacing the polluting power units. Several of the most famous producers of these installations are:

- French firms – *Vergnet, Travere, SFER, Aeroturbine* (0,1 – 30 kW).
- American firms – *Bergez Windpower* (850 W – 10 kW); *Southwest, Windpower* (<1 kW) – *coupled systems with photovoltaic modules; Atlantis* (0,3 – 6 kW);
- Dutch firm – *LMW* (250 W – 10 kW).
- Danish firm – *Windmissions* (600 W – 4 kW) – systems adjusted to the household necessities etc.

In 2000, the sales in the domains of producing and selling of small wind installations have totalized 680 milion Euro. There are several specialized firms in developing and manufacturing mechanical wind installations: Motzan Win-dKraftanlangen; AdPum AeroCraft, Vetroen (Russia) etc.

Table 3.4. Producing firms of small air-generators

Firm	Country	Range of capacity, kW	Specific price Euro/kW
		Autonomous systems	
Enercon	Germany	1-30	5,980
Vergnie	France	1-30	
Trovere	France	< 5	
SFER		< 5	
Air-turbine		< 5	
Bergey Windpower	USA	800 W – 10 kW	
Soutwest Windpower		<1 kW supplementary equipment with photovoltaic cells	
LMW	the Netherlands	250 W – 10 kW	
Windmission	Denmark	600 W 4 kW adjusted to the necessities of household consumers	
Atlantis	USA	0.3, 0.6, 6 kW	8,575-2,130
SUNSET		0.02, 0.2, 0.7 kW	2,400
SoWiloEnergietechnik		0.12, 0.24, 0.5, 0.75 kW	9,170-2,900
Solovent		0.14, 0.5, 3.2 kW	6,100-2,100
W+W Windtechnik		1, 3, 8 kW	27
Windtechnik Geiger		1, 1.7, 3, 4 kW	3,450-2,370
Landmark Alternative Energie		0.25, 0.6, 1.5, 3, 6 kW	570-1,875
Windtower Moratec Elektro Planungs		0.1, 1.5, 3.5, 7 kW	6,800-2,100
Bergez	Great Britain	1, 1.5, 7.5, 10 kW	630-2,600

3.1.3.6. Criterions of locations selection

The most favorable for using wind energy are the locations with the following weather conditions:

- the as high as possible average wind velocity – the main specific feature, which determines the annual energy production;
- as stable as possible wind flow that assures a stable generation regime;
- the presence of a dominant wind direction, fact that afford a more compact location of air-generators, in some wind farms case.

Alongside the mentioned weather specific features, the following factors have an almost decisive role of selecting the emplacement:

- the existence in the proximity of roadways and electrical networks;
- economic factors – for example, the land price;
- ecological restrictions - migration ways of birds, natural reservations, etc.) or those imposed by the security of the air transport;
- the impact on the environment, like: the noise, landscape deterioration, radio and television disturbances.

Favorable conditions for transport and the less expensive access to the electrical network, are ensured in the RM due to the well developed road system and electrical networks. The distance from any given location to the hard surface roadway, does not exceed, usually, 5-6 km. An eventual power line of connecting the station with the 10 kW network also will not exceed 5-10 km and will allow the decrease of the cost for building wind energy power plants.

We notice also the fact that the cost of land for the future plant locations represents an important economic factor. From the meteorological point of view, the most favorable are the crests and the superior hills slopes. These terrains, usually arid, with poor soils, less favorable for agriculture are used as pastures. The cost of the related sites will be minimal, especially that at the finishing of construction will be returned the same old destination, without supplementary expenses.

Restrictions towards wind plants construction can be set only on the territory of natural reservations.

In case of small installation the main criterion for choosing the location, are:

- the place for the turbine installing should be opened on a radius at least of 50 tower heights, the surroundings following to be free, that means without obstacles (buildings, trees, wood strips, orchards, etc.);
- the location should be chosen on prevailing hills;
- it would be better if the selected place would be as close as possible to the energy user (house to be fed with energy, water sources in case of pumping etc.)

The selection of the location will be preceded, in all cases, by a rigorous technical and economic calculation. Other specific recommendations towards different types of wind energy consumers can be found in the specialized literature.

3.1.3.7. Prospect location in the Republic of Moldova

Analyzing the upper exposed requirements, we can state that in the RM's conditions, the most important selection criterion is the meteorological one. From other points of view, the conditions are favorable for almost any territories outside the rural and urbane localities.

Totalizing the obtained results regarding wind energy atlas on country's territory by means of required wind installation locations, there could be stressed out the following prospect locations, outlined on the map in figure 3.6:

- Tigheci heights;
- Dniester's heights;
- Ciuluc hills;
- Heights of Central plain of Moldova;
- A significant part of the Cahul and Taraclia hilly territories.

As a result of some minute calculations, there could be also praised prospect location on the marked as less favorable territories on the map. These can be some high hills oriented towards the wind prevalent direction, territories on the shore of large water basins (Dubasari, Ghidighici, Ialoveni).

3.1.4. Estimation of costs, economic and social benefits as a result of wind energy sources implementation

3.1.4.1. Comparative analysis of European production air-generators

The main goal of this presentation is to outline the types of air-generators manufactured in serial production and that can ensure a maximum technical and economic effect in the wind conditions existent in Republic of Moldova.

The technical parameters of 48 types of air-generators with a capacity till 2000 kW, manufactured by European firms, recognized as leaders of this domain, are included in table 3.5, the used notations being:

P_N – capacity, in kW;
D_R – diameter of turbine rotor, in m;
H_O – tower's height till the rotor's pin, in m
S_r – area of the surface scavenged by the rotor, in m^2.

Considering the diversity of the aerogenerators technical parameters, in order to make a comparison, there were determined the following generalized technical indicators:

k_s – specific energy intensity that corresponds to the wind energy intensity at 1 m^2 surface and ensures the air-generator's capacity:

$$k_s = \frac{P_N}{S_r}, \qquad kW/m^2 \tag{3.1}$$

$k_h = \frac{V_h}{V_{st}}$ – height factor, which reflects the increase of the wind velocity at the same time with the increase of the height from the soil, is calculated in accordance with relation(3.2):

$$k_h = 0.233 + 0.656 \times \lg(H_0 + 4{,}75); \tag{3.2}$$

k_i – integral factor "area-height":

$$k_i = {k_i^3}/{k_r}. \tag{3.3}$$

The relation (3.3) includes k_h cubic factor, because the developed turbine power is proportional with the wind velocity cube, and k_r is placed at denominator, as the turbine will be considered the more performant, as the specific energy intensity of the wind at which this can generate energy is lower.

Table 3.5 includes the calculated synthetic indicators k_s, k_h and k_i. The last column indicates the related air-generator rating determined according to the value of k_i indicator.

The most performant, from this point of view, are air-generators with a capacity of 1,000 and 1,200 kW of DiWind, NEGMicon, Vestas types, as well as those of 600 kW produced by the same firms. Much more modest results are registering air-generators of 200-300 kW, the majority being designed between 1985-1995, much before those of 600-2,000 kW.

Table 3.5. Technical parameters of some aerogenerators with a capacity up to 2,000 kW, produced by European firms

Wind generator model	P_N	H_0	D_r	S_r	k_s	k_h	k_i	Rating
	KW	m	m	m²				
Bonus 1.3/62	1,300	68	62	3,019.1	0.431	1.45	7.14	30
Bonus 1000/54	1,000	70	54.2	2,307.2	0.433	1.46	7.21	27
Bonus 450	450	35	37	1,075.2	0.419	1.28	5.04	43
Bonus 600	600	58	44	1,520.5	0.395	1.41	7.14	31
DeWind D4/46 60 m	600	60	46	1,661.9	0.361	1.42	7.95	16
DeWind D4/46 70 m	600	70	46	1,661.9	0.361	1.46	8.66	11
DeWind D4/48 60 m	600	60	48	1,809.6	0.332	1.42	8.66	10
DeWind D4/48 70 m	600	70	48	1,809.6	0.332	1.46	9.43	3
DeWind D6/60 60 m	1,250	60	60	2,827.4	0.442	1.42	6,49	34
DeWind D6/62 65 m	1,250	65	62	3,019.1	0.414	1.44	7.25	25
DeWind D6/62 68.5 m	1,000	68.5	62	3,019.1	0.331	1.46	9.32	5
DeWind D6/62 91.5 m	1,000	91.5	62	3,019.1	0.331	1.53	10.90	1
DeWind D6/64 68 m	1,250	68	64	3,217.0	0.389	1.45	7.92	17
DeWind D6/64 91.5 m	1,250	91.5	64	3,217.0	0.389	1.53	9.29	6
DeWind D8/80 80 m	2,000	80	80	5,026.5	0.398	1.50	8.45	13
DeWind D8/80 95 m	2,000	95	80	5,026.5	0.398	1.54	9.26	7
Genesys 600	600	61.6	45.9	1,654.7	0.363	1.43	8.03	14
NEG Micon NM 1000-250/60	1,000	80	60	2,827.4	0.354	1.50	9.50	2
NEG Micon NM 1500C/60	1,500	80	64	3,217.0	0.466	1.50	7.21	26
NEG Micon NM 2000/72	2,000	80	72	4,071.5	0.491	1.50	6.84	33
NEG Micon NM 600-150/48	600	70	48	1,809.6	0.332	1.46	9.43	4
NEG Micon NM 750-200/48	750	70	48.2	1,824.7	0.411	1.46	7.60	21
Nordex N-29/250kW	250	50	29.7	692.8	0.361	1.37	7.18	28
Nordex N-43/600kW	600	78	43	1,452.2	0.413	1.49	8.02	15
Nordex N-50	800	70	50	1,963.5	0.407	1.46	7.67	20
Nordex N-54	1,000	70	54	2,290.2	0.437	1.46	7.16	29
Nordex N-60	1,300	120	60	2,827.4	0.460	1.61	9.04	8
TurboWinds T400	400	34	34	907.9	0.441	1.27	4.70	46
TurboWinds T600/48 50 m	600	50	48	1,809.6	0.332	1.37	7.81	18
TurboWinds T600/48 60 m	600	60	48	1,809.6	0.332	1.42	8.66	9
Vestas V39	600	40.5	39	1,194.6	0.502	1.32	4.57	47
Vestas V39	500	40.5	39.5	1,225.4	0.408	1.32	5.63	41
Vestas V42	600	40.5	42	1,385.4	0.433	1.32	5.30	42
Vestas V44	600	40.5	44	1,520.5	0.395	1.32	5.82	38
Vestas V47-660/200 kW	660	76	47	1,734.9	0.380	1.48	8.59	12
Vestas V57	1,500	60	57	2,551.8	0.588	1.42	4.88	45
Vestas V63	1,500	60	63	3,117.2	0.481	1.42	5.97	37
Vestas V66	1,400	67	66	3,421.2	0.409	1.45	7.46	22
Vestas V66/1650-200	1,650	78	66	3,421.2	0.482	1.49	6.87	32
Vestas V66/1800-300	1,800	67	66	3,421.2	0.526	1.45	5.80	39
Wincon W600	600	45	45	1,590.4	0.377	1.35	6.47	35
Wincon W755/48	755	75	48	1,809.6	0.417	1.48	7.78	19
WindWorld W4800	750	50	48	1,809.6	0.414	1.3	6.25	36
WindWorld W5200	750	50	52	2,123.7	0.353	1.37	7.34	24
WindWorld WW750/52	750	50	52	2,123.7	0.353	1.37	7.34	23
WindWorld W3700 500kW	500	41.5	37	1,075.2	0.465	1.33	5.01	44
WindWorld W3700 550kW	550	41.5	37	1,075.2	0.512	1.33	4.55	48
WindWorld W4200	600	45	42	1,385.4	0.433	1.35	5.63	40

Applying the data of table 3.5 and the power curves P=f(V), there has been calculated the annual energy that could be produced by the related air-generator (Wa), for the wind conditions of the considered emplacement.

The calculations were performed applying the WAsP program, with the wind velocity distribution taken after Weibull. The appropriate results are presented in table 3.6.

Table 3.6. Possible energy potential to obtain with different air-generators on the same location

Wind generator model	Energy in MWh/year	Wind generator model	Energy in MWh/year
Bonus 450	848	DeWind D4/46 60 m	1,697
Bonus 600	1,642	DeWind D4/46 70 m	1,847
Bonus 1000/54	2,960	DeWind D4/48 60 m	1,800
Bonus 1.3/62	3,738	DeWind D4/48 70 m	1,953
NEG Micon NM 600-150/48	1,627	DeWind D6/62 68.5 m	3,219
NEG Micon NM 750-200/48	1,976	DeWind D6/62 91.5 m	3,701
NEG Micon NM 1000-250/60	3,127	DeWind D6/60 60 m	2,984
NEG Micon NM 1500C/60	3,922	DeWind D6/62 65 m	3,302
NEG Micon NM 2000/72	5,073	DeWind D6/64 68 m	3,552
Nordex N-29/250kW	589.731	DeWind D6/64 91.5 m	4,131
Nordex N-43/600kW	1,681	DeWind D8/80 80 m	5,881
Nordex N-50	2,072	DeWind D8/80 95 m	6,394
Nordex N-54	2,392	Genesys 600	1,713
Nordex N-60	4,338	TurboWinds T600/48 60 m	1,691
Vestas V39	988	TurboWinds T600/48 50 m	1,516
Vestas V39	984	TurboWinds T400	645
Vestas V42	1,091	Wincon W600	1,264
Vestas V44	1,172	Wincon W755/48	2,306
Vestas V47-660/200 kW	1,920	WindWorld W3700 500 kW	852
Vestas V57	2,631	WindWorld W3700 550 kW	854
Vestas V63	3,192	WindWorld W4200	1,202
Vestas V66	3,258	WindWordl W4800	1,601
Vestas V66/1650-200	3,942	WindWorld W5200	1,887
Vestas V66/1800-300	3,846	WindWorld WW750/52	1,894

For the next step of the comparative analysis, there has been choused the energy criterion – the coefficient of utilization air-generator's installed capacity, K_u, calculated as:

$$k_u = \frac{Wa}{8760 \cdot P_N} \qquad (3.4)$$

According to the K_u indicator, the most performant are air-generators previously well ranked by the K_i indicator:

A third comparison was performed on the technical and economic criterion – the capital specific investments, which are determined as:

$$I_S = \frac{I_{AG}}{P_N} \qquad (3.5)$$

where: I_{AG} – represents the air-generator investment cost, in euro;
P_N – air-generator installed capacity, in kW;

In table 3.7 there are presented the results of the calculation for 7 types of aerogenerators, the most according to the first two mentioned indicators. The last column of the table contains the aggregate's rating, according to the I_s criterion.

Table 3.7. Technical and economic indicators for 7 types of air-generators produced in EU countries

Wind generator model	k	I_S, Euro/kW	Rating
Bonus 1000/54	0.338	899	1
NEG Micon NM 1000 – 250/60	0.357	1,007	4
Nordex N – 29/250 kW	0.269	951	3
Nordex N – 60	0.381	1,163	7
DeWind D4/48 70 m	0.372	933	2
DeWind D6/62 68.5 m	0.367	1,071	5
DeWind D6/62 91.5 m	0.422	1,118	6

On the basis of the table 3.5-3.7 data, there can be formulated the following conclusions:

- both the technical and economic indicators for installations with a capacity of 600-1,200 kW, are almost identical;
- specific capital investments in air-generator's varies depending on the capacity and the producing firm, being comprised in the limit of 890-1,170 Euro /kW and having an average price of 950 Euro / kW;
- the coefficient of utilization of the installed capacity for the considerate locations wind conditions is sufficiently high (up to 0.4222);
- feasibility study concerning implementation of wind energy power plants in RM, are following to be performed for three types of aerogenerators of 250, 600 and 1,000 kW, which parameters and technical / economic indicators are presented in table 3.8 and suit the generators with best performances in the related class.

Table 3.8. Three classes of most suitable air-generators: technical parameters

Type	P_N kW	D_r m	H_0 m	$k_{S,}$ kW/m^2	k_h	$k_{l,}$ m^2/kW	k_u	$I_{S,}$ Euro/kW
Nordex N-29	250	30	50	0.348	1.370	7.44	0.269	951
DeWind D4	600	48	70	0.332	1.462	9.40	0.372	933
DeWind D6	1,000	62	91.5	0.331	1.534	10.9	0.422	1,118

3.1.4.2. Economic indicators of investment projects in wind energy power plants constructions

A) General condition of economic efficiency.

The calculation of economic indicators will be performed using the general concept of economic efficiency appraisal, used in the countries with market economy, as well as some important recommendation regarding the evaluation of investment projects in RES. Defined in [6, 16, 17].

In order to prove the economic efficiency of the investment project it is necessary to perform the cost-benefit analysis, by which, finally, there are valued all the financial efforts (costs) foreseen in the project, on one hand, and all the effects (benefits), which will result of its implementation, on the other hand. In these conditions, the project is worth to be implemented only in the situation, in which the expected effects exceeds the accomplished efforts, that is, when there exists a net positive effect. This requirement represents the general condition of economic feasibility of the investment project.

In the economic literature, the accomplished efforts of a project are identified with the total s for the projects lifetime, the effects – with the gross income, and the net effect – with the net income.

Considering the necessity of discounting the efforts and the effects, according to those exposed higher, we can write –

$$NPV = DGI - DTC \qquad (3.6),$$

where: *NPV* – represents the net discounted income (or the net present value – NPV), over the study period;

DGI – discounted gross global income;

DTC – discounted total costs;

A project is being considered advantageous, in case if the gross profit DGI exceeds the total cost DTC, that means that the net discounted income, obtained as a result of generating energy during the study period is positive – $NPV > 0$.

These relations specify the general condition of feasibility. The valuation of efforts and effects, and subsequently – their comparison – assume to take into consideration some factors as:

- the determined efforts and effects for a long time period T_s, known as the study period or the analysis period, which, as a rule is equal to the service life of installations, T_s = 15-20 years;
- both the efforts, and the global effects over the study period, must be discounted, (reported to a certain time point, usually the present one), at a rate which is going to be settled;
- the benefit calculation, which in the examined case, represents the monetary value of the generated energy, suppose that the utilization of the opportunity cost of 1 kWh electrical energy, which follows to be settled;
- long-range forecasts contains significant errors. In these conditions, the effects which will result will comprise an advanced degree of uncertainty – that does, on one hand, that the calculations, to be more laborious, and on the other hand the final decision making process – more difficult.

Taking into account the related considerations, the analysis of this kind of projects is performed using a maximum number of indicators.

B) Definitions and calculation formulas of economic efficiency indicators.

The *cost-benefit* analysis is a part of a large domain – that of investment efficiency, which is characterized by a system of indicators, as:

Net present value;
Internal rate of return;
Discounted total cost;
Payback period.

In case of a generating system of renewable energy, to these indicators will be added also others, specific to this domain, such as: *the volume of the generated renewable energy, its cost, the continuity of energy generating*.

An investment as a rule, is effected having as goal to obtain profit. From this point of view, profitability represents the most important side of the investment project. Profitability is estimated by the means of several indicators, including *the net present value (NPV)*, for the period of the project lifetime.

Net income or ***annual benefit***, represent the total profit part, obtained during the year (gross income), left after deducting of all costs during the related year were excluded. For a certain t year of the study period:

$$NI_t = V - TC_t,$$

where: NI_t – represents the net income estimated to be obtained during the t year;

V – the gross income estimated for the t year;

TC – total cost estimated for the t year, which include investment cost I_t and those of exploitation C_t, excluding payments.

$$Thus,\ TC = I_t + C_t.$$

For an energy source, the gross profit P_t represents the value of generated energy:

$$P_t = W_t \cdot C_w ,$$

where: W_t – volume of generated energy in year t;

C_w – opportunity cost of a kWh of generated energy;

The net present value (NPV) for the study period *(T_s)* is determined by summarizing the net discounted annual profit.

$$NPV = \sum_{t=t_i}^{T_s} PV_t (1+i)^{\theta - t},$$

where: t_i and T_s represents the first and the last year of the study period;
i – discounting rate;
θ – reference year for discounting.

The net present value can be calculated as the difference of the discounted total income (DTI) and discounted total cost (DTC):

$$NPV = DTI - DTC$$

where: $DTI = \sum_{t=t_i}^{T_s} V_t (1+i)^{\theta - t}$; $DTC = \sum_{t=t_i}^{T_s} (I_t + C_t) \cdot (1-i)^{\theta - t}$;

For a project with the initial investment effected in the first year, with a constant annual gross profit , constant annual cost C and with the study period S years, the net discounted income will be determined as:

$$NPV = (V - C)\sum_{t=1}^{T_s}(1+i)^{-t} - I$$

The net present value is one of the most important indicators of investment economic efficiency. Achieving a profit as greater as possible, as a rule is the priority criterion for choosing the optimal solution.

Discounting of costs and incomes assumes the utilization of a predetermined value of the i discounting rate that also has an other signification – it represents an economic efficiency indicators, called **Internal Rate of Return** (IRR).

Internal rate of return of an investment project expresses such a rate i that equals the discounted values of the total income and total cost for the entire study period, determined by the equation:

$$NPV\,(IRR) = 0$$

For specific conditions, when $V_t = const; C_t = const$ and the capital investments are performing a year, at the beginning of the study period, IRR will be determined by the equation:

$$\frac{I}{PV} = \sum_{t=1}^{T_3}(1+IRR)^{-t} = \frac{1-(1+IRR)^{-T_s}}{IRR}.$$

Payback period or ***the recovery period*** of the investments T_{rec}, is an indicator which express the number of years during which the initial investment can be recovered by the obtained profit. For the typical case of an implementing project of wind energy sources the investment pay-back period will be determined by the equation:

$$\frac{I}{PV} = \frac{1-(1+i)^{-T_{rec}}}{i}$$

The construction of a wind installation is justified then, when the investment payback period is under the level of the average pay-back period of the energy sector.

The cost of the delivered electrical energy is the most important economic efficiency of an energy source. In the feasibility study this indicator is calculated as a ratio of the total discounted cost to the total discounted amount of over energy produced over the study period:

$$C_w = \frac{TDC}{W_{disc}}$$

where: TDC – represents total discounted cost (investment plus production costs);

W_{disc} – the total discounted amount.

In the case in which the volume of the generated energy doesn't vary from year to year and is equal to W_{disc}, there can be written the following relation:

$$C_w = \frac{AC}{W_{act}}$$

where: AC – is the annual cost which includes the annual depreciation charge *(D)*, and the annual production cost *(C_p):*

$$AC = D + I_a + C_p .$$

In case of renewable energy sources, that does not assume cost for fuel, the calculation formula for the cost of 1 kWh electrical energy, becomes:

$$C_w = I_S \cdot (E_e + \alpha_E) / T_m ,$$

where: I_s – specific investment in RES;

E_e – capital recovery factor;

$$E_e = \frac{i}{1-(1+i)^{-T_s}}$$

α_E – operation and maintenance cost, reported to the investment;

T_m – the period of utilization of the installation's capacity, (T_m = 8,760 k_u) in hours;

k_u – usage coefficient of air-generator's installed capacity;

3.1.4.3. Capital investments in wind energy power plant construction

A) Capital investment structure

The capital investments in construction of a WEP consist in two basic components: air-generator's cost and the cost of the engineering infrastructure, of the electrical equipment that ensures its operation. The air-generator's cost corresponds to the price they are being sold at the factory and doesn't include the cost of engineering constructions, of the supplementary electrical equipment and of the assembly works. The mentioned cost and those related to the projection and the management of capital investments is presented in figure 3.12.

B) Air-generator's cost

The air-generator delivery price, selected from the price lists of the producing forms for different types of installations have been presented in table 3.7. from this table, there can be observed that the cost of 1 kW of the air-generator's installed capacity constitutes from 890 to 1,170 Euro. In the following calculations there will be utilized the established costs for synthetic air-generator's from table 3.8.

The cost of transportation of the air-generator from the factory to the place of installation, the assemblage, the start-up cost of operation and maintenance during the term of guarantee are established by the producing firm, usually, as calculated as percents of the air-generator's initial cost. Approximate data regarding the structure of these costs are presented in table 3.9.

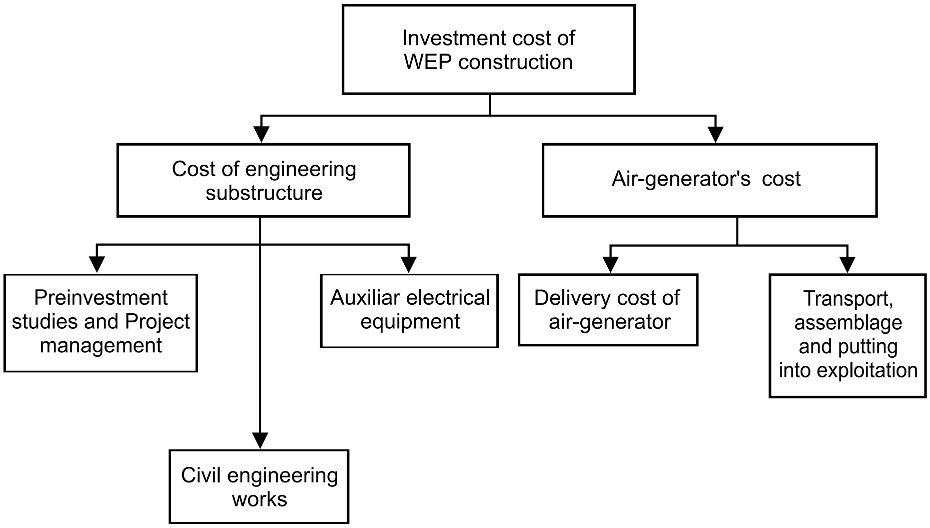


Figure 3.12. The structure of the investments in wind energy power plant (WEP)

Table 3.9. The structure of air-generator cost regarding the transport, the assemblage, the exploitation

Denomination of works and services	Cost as initial % of the air-generator's cost
Transportation and insurance	3.2 %
Spare parts, wear and tear-parts, tools	1.5 %
Works of assembly, start-up and local personnel training	3.0 %
Total	7.5 %

C) The cost of engineering substructure

The construction works include:

- foundations construction;
- construction and completion of the installation of power and control cable;
- the construction of approach and communication.

The cost of electrical substructure includes:

- the cost of voltage control station;
- the cost of 10 kV of overhead electrical line for connecting to the public network.

The project design cost, engineering insurance and construction management include also cost for:

- geological terrain studies and performing a study;
- investigations, including experimental, regarding the wind energy potential in the location zone;
- pre-design and design of the wind energy power plant (WEP).

The cost regarding the setting up of the engineering substructure are assessed at the stage the project design, considering the local conditions, including the labor price.

For technical and economic appraisals, as a rule there are utilized the generalized results after prototype. The total cost of the designs works and construction works, as well as the WEP equipment one (excepting air-generator) is estimated to 15-30 % of the project total cost.

In the case of the RM, there can be accepted the minimal figure of 15 %, considering the low labor cost and the fact that both the length of access and connection lines to the public network of possible WEP's will be small (<10 km), as the road system and electrical network in the country are enough developed.

D) Example of calculation

There is considered a WEP with a capacity of 3 MW, placed in the immediate neighborhood of the meteorological station of Ceadir-Lunga. There are examined three variants of air-generator equipment:

Variant 1: 12 air-generators AG1 with P_N = 250 kW;
Variant 2: 5 air-generators AG2 with P_N = 600 kW;
Variant 3: 3 air-generators AG3 with P_N = 1,000 kW.

The results of these calculations are presented in table 3.10.

Table 3.10. The cost of capital investments components in a WEP construction of 3 MW

No.	Investment component	Cost, in thousands of Euro		
1.	Type of air-generator	AG1	AG2	AG3
2.	Number of air-generators	12	5	3
3.	Cost of air-generators	2,935	2,800	3,354
4.	Supplementary cost for off site transportation, assembling and start-up	220	210	235
5.	Cost of engineering substructure	540	540	540
6.	Total capital investments in WEP (6)=(3)+(4)+(5)	3,695	3,520	4,129
7.	Investment cost of 1 kW of installed capacity: (6)/3,000, in Euro/kW	1,232	1,176	1,376

The obtained results are fully confirmed with the costs, regarding capital investment structure.

3.1.4.4. The Estimate of production costs

At the generation of electrical energy, the production costs include:

- the fuel cost (in case of wind stations this is not taken into account);
- operation and maintenance cost;
- bank expenses, for terrain leasing for the WEP emplacement.

As usual, for the preliminary estimate of energy efficiency of the WEPs, it is recommended [17] the annual charges for operation and maintenance at the level of 1-2 % of the plant capital investment.

In [18], the operation and maintenance cost are assessed at the level of 25 Euro/kW/year, in the case of 200 kW installations and about 15 Euro/kW/year for installation of 500 kW.

In both cases, there are being obtained quasi identical results.

3.1.4.5. Assessment of economic efficiency of the wind energy power plants in the RM conditions

More factors, make us believe, that in the RM's conditions, a large spread will have the relatively small WEPs, with a installed capacity of 3-8 MW. Among these factors, the financial one should be firstly outlined. It will be harder to invest at one 10 millions Euro from external loans or internal accumulations. In order to obtain the greatest effect of the wind energy, the plants should be placed in the immediate neighborhood of consumers.

Table 3.11 presents the results of economic indicators calculations for a possible wind plants, built in the proximity of Ceadir-Lunga (county), for the location of which there are known the wind conditions (*figure 3.5*). There are examined three variants of plants endowment with air-generators (*table 3.11*). The calculations were performed supposing that the lifetime of the main equipments T_s = 15 years; discounting rate i = 0.1, typical for energy projects; the a_E = 0.01 of the capital investments.

In these conditions, the production cost of electrical energy will constitute 0.0508 – 0.067 Euro/kWh, depending on the considered endowment options.

There can be observed that the highest efficiency is obtained in the case of air-generator with the capacity of 0.6 MW each, followed by the air-generators of 1 MW. Capital investments in this case, are maximum, but due to the greater volume of annually generated energy, the electricity cost is lower. The 2nd and 3rd variants do not differ a lot according to considered economic indicators.

It is known the fact that at the settlement of the purchase price and the delivery tariffs of electrical energy, there are considered more factors, including social and political.

On the purchase cost will influence a lot also the time factor. For example, in the majority of counties there are significant tariff increases (up to 30 %), if the energy is generated in the rush hours and in the of maximal load months (December – February). The daily and seasonal wind chart in the Republic of Moldova is favorable in this respect. Greater wind velocities are being registered between 7-9 a.m. and between 14-18 p.m.; the greatest wind intensity is being observed in January-February, that is exactly the period when the energy demand is maximum.

Table 3.11. Calculation results of economic indicators for a 3MW wind energy power plant

No.	Parameter, indicator, criterion	Variant		
		1	2	3
1	Installed capacity of WEP, MW	3	3	3
2	Type of air-generator (tab. 3.8)	AG1	AG2	AG3
3	Nominal capacity AG, kW	250	600	1,000
4	Number of air-generators	12	5	3
5	Utilization factor of nominal power, k_u	0.304	0.372	0.42
6	Volume of annually generated energy, thousands kWh/year	7,989	9,776	11,037
7	Volume of generated energy W_a, during the discounted plant lifetime, thousands kWh	60,742	74,356	83,947
8	Discounted air-generator lifetime T, years	7.606	7.606	7.606
9	Investment in WEP (from table 3.10), /thousands Euro	3,753	3,523	4,117
10	Specific investment in WEP, Euro	1,233	1,276	1,370
11	Annual operation expenses, in relative units, a_E	0.01	0.01	0.01
12	Average operation expenses $C_{ex}=a_E \cdot I$, thousands Euro	37.5	35.2	41.7
13	Annual cost of the initial investment and of the loan, R_I, thousands Euro	492	461	539
14	Average annual cost AC, thousands Euro	529	496.2	581
15	Discounted total cost for the installations lifetime, DTC, thousand Euro	4,024	3,791	4,429
16	Cost of generated energy, C_N, Euro/kWh	0.067	0.0508	0.0527
17	Existing electricity tariff for the public network, Euro / kW	0.07	0.07	0.07
18	Gross annual income obtained from the energy delivery, V_{an} thousands Euro	559	684	772.6
19	Net annual income, V_N,thousands Euro	521.5	648.8	730.9
20	Discounted gross global income, DGI, thous. Euro	4,252	5,203	5,876
21	Net present value, NPV, thous. Euro	1,228	1,412	1,447
22	Payback period, T_{rec},in years	13.3	8.24	8.7
23	Internal Rate of Return, IRR, in %	11.0	16.5	15.8

In the Republic of Moldova, till nowadays there have not been elaborated a approved a policy regarding the tariff for electrical energy. The purchasing prices of electrical energy reported to the European ones are very low (0.20-0.39 MDL/kWh), fact that is explained only by the very low allocations repowering the energy production units. The state of power plants and transport network in the country is lamentable. Many of financial necessities of this sector have been covered during the years from the state budget endowments.

In [19] is examined the situation of the energy branch of the Ukraine, situation similar to the existent one in the Republic of Moldova. According to the conclusions of this study, performed at the GOSNII Institute of Researches, for preventing a complete break up of the energy sector in the following years, there will be necessary considerable investments, which could be accumulated by increasing electricity tariffs by 4-8%. Thus, towards 2010, the tariffs for electricity could achieve the level of present average tariffs applied in EU [18, 20].

The increase of the production cost of the electrical energy in the next years will be imposed by the stepped growth of fossil fuels prices on the global market.

Another very important factor, which could determine the electricity distribution to purchase the energy from wind energy power plants at a higher price, is their location in the immediate neighborhood of the consumers that are situated far away from the power plants. If, there will be decided to build power plants in the south of republic and respectively in the north, they would meet an important part of the energy demand of the counties and villages of this regions. Thus, it won't be necessary to transport energy of any power plant of Ukraine or CHP-2 Chisinau. At the same time, it would be avoided the losses of transportation and double energy transformation at the stations of increasing and decreasing the voltage. This cost component can constitute 25-50 % of the delivery price of electricity.

At a possible internalization of environmental cost into electricity tariff (table 3.12) [21] for power plants on coal, natural gas or oil, the electricity generation at the wind energy power plants would be more profitable, comparing to the obtained one from the power plants.

Table 3.12. External costs of electricity generated by different technologies, in Euro cents / kWh

Country	Coal and lignite	Oil	Natural gas	Nuclear fission	Biomass	Wind energy
Germany	3 – 6	5 – 8	1 – 2	0.6	3	0.05
Denmark	4 – 7	–	2 – 3	–	1	0.1
Spain	5 – 8	–	1 – 2	–	3–5	0.2
France	7 – 10	8 – 10	2 – 4	0.3	1	–
the Netherland	3 – 4	–	1 – 2	0.7	0.5	–
Portugal	4 – 7	–	1 – 2	–	1–2	0 – 0.15
Great Britain	4 – 7	3 – 5	1 – 2	0.25	–	0.15

Source [21]

In figure 3.13 are presented the calculations results regarding the dependence of the pay-back period of the capital investments T_{rec} of the energy delivery tariff T_W, calculated for the second variant (with AG2 air-generator). If at a tariff of 0.06 Euro/kWh the investment recovery takes 10.4 years, at the tariff of 0.08 Euro/kWh, - will reduce to 6.7 years.

As a conclusion, we will mention that in the south zone of the RM, there have been outlined numerous locations with wind conditions better than those of the examined location higher, and implicit, with possible superior economic indicators.

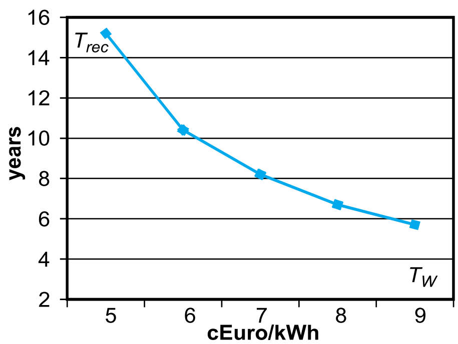


Figure 3.13. The payback period for the capital investments T_{rec} depending of the energy deliver tariff T_w

3.1.5. The assessment of environment benefits as a result of wind energy implementation

3.1.5.1. General aspects

In previous paragraph there has been examined the technical and economic aspect of using wind energy in the RM's meteorological conditions. There has been stated that on the country's territory exist enough zones with favorable conditions for building wind energy (farms) plants on the basis of air-generators with a unit power of 600 – 1,000 kW, which could generate electrical energy at convenient prices, competitive with the ones generated by classical power plants, especially by those, which are following to be built.

In these conditions, in order to outline the advantages and disadvantages of the wind energy sources comparing to the classical ones, these should be examined by means of the multitude of social, political and environment factors, which directly or indirectly – will generate either benefit, or losses for private persons, but especially for the society as a whole.

Among the environment factors, there should be emphasized the following, as the most important:

- the quantity of green house gases (GHG), which cause the climate change;
- the quantity of SO_2, NO_x, oxides dust, ashing and other pollutants;
- alienation of agricultural terrains;
- phonic and electromagnetic environment pollution;
- landscape change;
- ecological impact (on flora and fauna).

3.1.5.2. Environment benefit

Each kWh of electricity generated by a wind farm replaces 1 kWh generated at a thermoelectrical station in the result of burning a certain quantity of organic fuel (coal, oil or natural gas). In this case, its easy to estimate the avoided quantity of polluting gas, due to the use of wind energy.

There are known the CHPs specific emission rates for generating electrical energy (*table 1.2*). It follows just to determine the wind energy quantity, which is expected to be generated and used in the country.

Although in the Republic of Moldova, there was not yet elaborated a specific program regarding wind energy implementation, there can be made certain optimistic forecasts. It will be started with the condition of stability of the power system, which limits the wind energy quantity accepted by an energy system. The electrical energy generated by a wind energy plant has a poor quality, having unstable parameters and first of all a variable production capacity. The wind energy plant will deliver electrical energy to the network, depending on the wind energy potential. The other energy sources (power plants) must cover permanently the difference between the demand and supply of energy. It is considered [23], that if the wind energy plants quota does not exceed 20 % of the total generating capacity, the system will operate constantly, thus ensuring the standard – parameters conditions, taking into account the coefficient of utilization of the air-generator's installed power, we can state that the wind energy plants can operate without difficulties – as a component of the contry's power system, having a rate of generated energy about 10 % of the total volume of annually used energy.

If, for example, the Republic of Moldova would propose itself, as a strategic task, to cover towards 2010, 10 % of internal demand (8.60 trillions kWh) with wind electrical energy, *thus the quantity of annually avoided CO_2 would constitute 735 thousands tons.*

Simultaneously, there could be also obtained a significant decrease of SO_2 and NO_x emissions, which have a considerable negative impact on woods, crops, generally on vegetation and particularly on the endangered species, considering that the caused damages of SO_2 and NO_x emissions are amounted to 6,000 Euro/ton [18], *the economic benefit as a result of avoiding the mentioned emissions will constitute about 27.2 millions Euro/year.*

Replacing a part of electrical energy generated at the power plants with energy generated by the wind, *there will be decreased the annual fossil fuel import by 282 thousand tons of coal equivalent conventional fossil fuel*, that will have a positive impact on the degree of security of supply.

Table 3.13. Avoidance of GHG emissions as a result of wind energy utilization

Parameters	Quantity, 2010
Generated wind energy, in millions kWh/year	860
Avoided emissions, in thousands tons/year, including	
of CO_2	735
of SO_2	2.46
of NO_x	2.08

The implementation of wind energy is also accompanied by some negative effects, like: electromagnetic and phonic pollution, alienation of planted land and landscape change.

The modern wind turbines have a low speed (20-40 rotations per minute) and their air-dynamics is very rigorously projected, following the goal of reducing to minimum the noise level.

In the figure 3.14, there is presented the dependence between the noise level and the distance from the tower, characteristic for a wind turbine of 1 MW. To a certain distance, the turbine's operation can not be perceived. If at 40 m from the wind energy plants tower the noise does not exceed 50-60 decibels (dB) – level characteristic to a common conversation, then at 500 m from a wind farm with several turbines inside a building the noise level is 35 dB, level characteristic to a commercial center. There can be stated that the sonorous effects of the wind energy plants are net inferior as comparing with those registered on the motor roads, that cross the majority of towns.

Electromagnetic pollution, which can influence the telecommunication systems, is detected only in case of using turbines with metallic blades. At present, in the process of blade manufacture, especially those with large powers, there are used non-metallic materials – pitches, glass and plastic fibre. Thus, the problem of electromagnetic pollution has been removed.

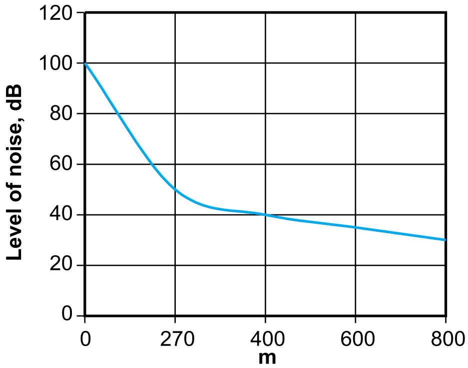


Figure 3.14. The dependence of the noise of the distance from the tower of 1 MW air-generator

In the case of wind (farms) energy plants, the required surface for their location is much more reduced in comparison with the grounds withdrew of the available land for classic energy. In order to obtain a GWh of electrical energy, for a period of 30 years, there will be necessary a territory with a surface of 200-1,335 m^2 for a WEP and a surface of 3,642 m^2 for the same output at a classic power plant [18]. Towards 2005, Denmark is planning to dispose of a wind farm complex with about 1000 turbines, placed on a territory of 100 km^2 and which will produce 10 % of the total electrical energy, consumed in the country. It should be noted that only 2% of this territory will be occupied by the tower's foundations.

It is considered that up to 90 % of the occupied territory of a wind farm can be used for agricultural works or grazing. There have not been noticed any effects, that would prove that the operation of wind turbines influence negatively the situation or the productively of domestic animals or the personnel's health, which spend a long time period nearly them.

The wind farm aspect, has an importance, that should not be neglected. The reaction to the form of air-generators is subjective, but it matters to the public opinion formation. The wind farm can complete or change the image of the local landscape. It's already known the fact that air-generators with a tower of conic pipe are much more attractive that those with the tower having a farm of profiled metal form.

The successful design and colors can offer this pure energy objective an agreeable appearance. Thus, alongside the fact that they are generators of "pure" energy, the modern wind farms are attractive by their aesthetic value.

3.1.5.3. Social effects

Different studies confirm the fact that wind energy is preferable as regarding its capacity of creating work places, in comparison with fossil fuels power plants and the nuclear ones. The generation of wind energy is generally decentralized and occurs at a small scale and the manufacture of blades and other components requires a qualified labor, in order to ensure the proper quality. According to the European Association of Wind Energy, usually a capacity of 1 kW of wind energy creates work places for 15-19 persons, in the present conditions of European market, supporting that the related figure could double in the countries with intensive use of labor.

According to this supposition, for an installed power of 300 MW of the future wind stations, there could be created 4,500-9,000 new work places in the country, especially in the villages, where the unemployment achieved alarming rates.

At the same time, there could appear possibilities of participating both – in the process of manufacturing the equipment for the wind energy plants and their installation and employment of small firms based on private capital or even on the budget sources of local public bodies.

As an example, can serve Denmark, where the wind farms promotion is based on a decentralized model, having in the center its communities. In this country the installations are built by companies, financed by entrepreneurs and used by local farmers. Unlike the traditional huge energy projects, performed by corporations all over the world, the Danish variant has increased the earnings of small entrepreneurs and has created new work places in the communities.

The growth of RES share in the country's energy could considerable contribute to state energy security consolidation. Thus, the evolution of the power system would depend less on the whims of GAZPROM company in the first ranks being situated economic and political interests of the state.

The implementation of the of renewable energy sources would also have a positive influence on the public opinion, which would realize the necessity to protect the environment and to consume rationally energy resources.

3.1.5.4. Risks

Implementation of wind energy projects is associated with the following risks, that would diminish the foreseen economic effect.

Generally, the financial institutions examine four types of risks: political, currency, credit and risks of implementing the project.

1. *Political risk* suit the group of risks, controlled by the state authority. Such a risk can appear, for example, in case of modification of the legislation in force, or type of ownership, etc.
2. *Currency risk* could derive of the political one – as a result of national currency devaluation etc.
3. *Credit risk* overcomes as a result of the buyers incapacity to pay the purchased goods, or of the demand diminution, in this case, at electrical energy.
4. *Risk of implementing the project* appears as a consequence of certain events or causes that would hinder the project execution, including force majeur cases.

The first three types of risk will be minimal in case of political stability in the country, considering the particular interest manifested by the state authority toward energy and especially the attention paid to RES network development.

The risk of project implementation should be investigated in details, as comparing to analogical projects performed in the traditional energy (for example, the construction of a thermoelectrical plant).

Alongside with the basic risks, there can arise also other risks, such as:

Ecological risk, which suppose the increase of charges regarding environmental protection. This risk is excluded, as the wind station is a source of clean energy in regulation procedure, as well as in case of accident.

Social risk. In this case, the wind energy plant (WEP) is examined as a potential source of traumatism in production. Inside WEP there are few contact areas of personnel with turning, electrical, high temperature or other elements, which could cause traumatisms. Following the protection rules, the traumatism risk at WEP is reduced to minimum, being ten times smaller in comparison with the existent one at the thermoelectrical stations.

Technological and transport risk is examined as a risk of decrease of the energy output because of lack of fuel, water and other consumable. This risk is minimal as comparing to the one of CHPs, because at the wind energy plant there is no fuel or industrial water consumption. There does not arise either the transportation risk, due to which absence the plant could not be assured with fuel supply.

Production risk is connected with the decrease of the finite product volume (electrical energy), as an out of service consequence of installations or electrical substructure.

The wind installations manufactured nowadays, have exceed all the running in situations specific to the experimental test sample. Producing firms of wind installations guarantee their production, identical to the ones of the equipment of thermoelectrical plants.

The wind energy risk, has the greatest weight in the case of wind energy plant. A considerable decrease of energy generation is possible to arise if the average wind velocity or its repartition on gradations is performed incorrectly. Reductions can be caused by considerable changes of wind conditions that occurs in certain years.

This risk can be reduced by supplying basic energy calculations with multi-annual reliable data on wind and wind rose, including data obtained as a result of long term measurements on the plant's emplacement.

Force majeur risk can arise in the case of certain unordinary circumstances like frosts with sleet less characteristic for our region, but which have caused the deterioration of North Electrical Networks in the autumn of 2000. The probability of appearance of these situations is enough low.

3.2. Feasibility study regarding implementation of solar energy in the Republic of Moldova

3.2.1. Technological aspects regarding solar energy conversion

3.2.1.1. Types of conversion of the solar energy into secondary energy

There are known four types of solar energy conversion:
Thermal conversion means the direct transformation of the solar radiation into thermal energy stocked in internal energy of some liquid, gaseous or solid substances, so called working substances. The accumulated thermal energy can be used directly for heating, drying, etc., or indirectly by a secondary conversion into other type of energy – mechanical or electrical.
Electrical conversion uses some semi-conducting materials properties of transforming directly the radiant energy into electrical energy of continuous current.
Chemical or photochemical conversion allows the solar energy stocked in chemical energy. The most efficient photochemical process is photosynthesis, by which plants synthesize organic substances. By their firing the stocked chemical energy reconverts in thermal energy that can be used directly for heating or indirectly in thermal engines.
Mechanical conversion is a process of directly transformation of solar energy in mechanical one, by a momentum transfer between photons and working element or indirectly by the help of solar motors in which solar energy transforms into mechanical energy by means of thermal energy.

There should be mentioned that of the four types of solar energy conversion, thermal and electrical one are the most used in the world, having an advanced degree of technical and technological perfection, a developed sale market and economic prospects.

3.2.1.2. Thermal conversion of solar energy

The thermal conversion is the oldest and the most widespread form of solar energy utilization. Any black surface exposed to solar rays (called collecting surface/area) transforms the solar energy into heat. In order to improve the collector's efficiency and the energy's transportation there is utilized a liquid or a gas, called heat carrier (heat collector), which extracts the heat of the collector. In some systems the solar energy is transformed into heat and is immediately used, while in others – takes place the storage or transformation of thermal energy into electrical one.

Solar collectors of low and medium temperature. This category comprises systems of conversing diffuse and direct radiation in thermal energy at temperatures of up to 150 ^{0}C. Usually, these collectors include the following elements:

- A plate or an absorption surface, which transforms the solar radiation in heat;
- A liquid or gaseous heat carrier circuit, which extracts the heat of the absorption plate and transports it to the usage point or to the storage tank;
- One or more transparent surfaces for solar radiation, but opaque in the range of infrared radiation. The transparent surface is also called stained-glass;

- Thermal isolation of the absorption plate in the lateral and inferior parts;
- Tank for thermal energy storage;
- Carcass for assemblage elements.

Mainly, there are used two types of collectors: plane and with vacuum tubes. The plane collector is used for water or air heating. It has a simple construction. The absorption plate is made of metal or of plastic material through which circulates the heat carrier. These systems can supply water or warm air for sanitary necessities, heating of piscines, commercial and floor spaces, ventilation and air-conditioning, farm produce dehydratation, in industrial technologies of low temperature. More often, this type of collectors is used for water heating at 60 ^{0}C temperature, drying or farm produce dehydratation with a 40-60 % efficiency. The plane collector's technology is very advanced, the prices being in continuous decrease.

The collector with vacuum tubes is a more recent construction in which the thermal isolation is the vacuum of an advanced degree of the tube's interior, where also is situated the absorption plate. Its efficiency is about 50-70 %, thus ensuring the caloportor liquid heating up to 150 ^{0}C. These collectors' cost is about three times greater than the plane's one. It should be noticed that they are more fragile and the diminution of the tube's vacuum, leads to the loss of the main advantage.

Solar drying plants. This technology is one of the oldest and largely used in agriculture and in the food processing industry. The fruits and vegetables drying by direct exposion to the solar radiation is made on special grills with uniform layers. Although it's the simplest technology, it requires an attentive process execution, in order to protect the produce of rain, dust, dew, insects, etc. That's why more recommended is the drying under a transparent roof, which besides the produce protection, intensifies the drying process, thus achieving the greenhouse effect. The installations are cheep and easy to build, but present a range of drawbacks: low productivity and efficiency (15-20 %), the impossibility of controlling and conducting the process, unsatisfactory quality of the final product. The listed disadvantages are missing at the installations of indirect drying, in which takes place the pure convective drying and is avoided the vitamin's degradation in fruits and vegetables, as well as the active substances of medicinal plants. A ventilator operated by an electrical or wind engine and directed to the drying room is circulating the heated air of the plane collection, formed from the transparent and absorption surfaces. The quality of the dried product is net superior, the drying period is decreased by 1,7-2,0 times, as comparing to the type for direct drying. This technology can be used also for hay, cereals, nuts, drying wastes of the industry of farm produce processing: husks of grapes, apple and beet pulp, stones of apricots, peaches, plums, etc.

Solar distilleries. Solar energy is used directly for salt-water evaporation or for the water with a high grade of salts (characteristic for the South zone of the RM). The solar rays, cross the transparent surface, heat and evaporate the salt water of the reservoir. Rising, the vapors are condensing on the interior transparent surface, cooled by convection by the environmental air. The condensation elapses on the interior surface in the refuse spout.

This technology is utilized in isolated regions, where there are no other sources of potable water. In good conditions of solar radiation, about 5-6 kWh/m^2·day, the potable water productivity is 4 l/m^2 per collector that suits a 40-50 % efficiency.

Solar cookeries. It's about some solar installations, which operate on temperatures of 125-200 ^{0}C. There are used the following 3 categories:

- Case-cookery endowed with double stained-glass and plane viewing mirrors, thus being ensured a weak concentration of the radiation. Around the noon there can be achieved a 140-150 ^{0}C temperature.
- Cookery with a plane collector having a selective surface or vacuum tubes, equipped also with viewing mirrors. The heat carrier circuit is supplied with oil. There are being achieved temperatures of 150-180 ^{0}C.
- Cookery with concentrators. The cooker for preparing food is placed in the focal point of a concentrator, which ensures the thermal conversion only of the direct component of solar radiation. The installation requires a follow-up system of the sun and can ensure temperatures of several hundreds degrees.

Solar collectors of high temperatures. High temperatures of several hundreds, even thousands degrees that can be obtained by the solar radiation concentration, which consists in directing using a certain method of the solar radiation collected on a viewing surface towards another smaller, called receiver, where is performing the thermal conversion itself. The collectors with solar radiation concentration are endowed with a follow-up device of the sun either by a coordinate or by two. This technology is used in different industrial processes (for example, for fusing and producing pure metals), in producing electrical energy, hydrogen, water vapors, etc. From the large range of concentrators, we will stress out the following three, which are used more often:

- *Cylindrico-parabolical concentrators* ensure a concentrating factor of 40-80 % and temperatures up to 500 ^{0}C. The heat carrier liquid circulates through a pipe, which is situated in the parabolic cylinder focus. The sun pursuit is performed by a single coordinate – angle of elevation. This type of concentrators are sold on the market, the most spread being "Luz International" installations, which in the 90's of the last century, settled in California (USA), 9 power plants with a total electrical power of 360 MW [24]. The average cost of "Luz: systems is 2,500 $/ installed kW, the cost of electrical energy – 0.15 $/kWh. The accumulated experience by "Luz International" proves a possible electrical energy production at a competitive price in countries with a high level of solar radiation.
- *Paraboloidal concentrators* use a paraboloid reflector, which follows the sun by two axes. The direct radiation is concentrated in a single point, the concentration factor achieving values up to 10,000, the receiver's temperature being higher 1,000 ^{0}C. Thermal energy is collected by a caloportor liquid and transported towards a thermodynamic cycle in order to produce electrical energy or is transformed in electrical energy directly in the focus point, using Stirling engines. In the case of this technology its necessary to continue the researches on the Stirling engines, on heat

exchangers in the focus point, on viewing surfaces, having as a goal to decrease the costs and to increase the efficiency on long operation term.

- Central collector with heliostates. The focus point, or in other words the receiver is situated in the center of a teleguided viewing mirror field, called heliostats. A computer performs the control to each heliostate, thus that the reflected energy towards the receiver could be maximal during the day. Such installations can be compared by their capacity with the power plants, which operate on fossil fuel. It is considered that the power of 100 MW would be optimal and would ensure the electrical energy production for a price of 0.05$/kWh, at a usage factor of the settled capacity – 60 %. At present, the greatest solar plant with heliostates has a capacity of 10 MW (Solar One, USA). The cost of produced energy at this plant is 0.1$/kWh, the usage factor of the settled capacity – 38 %. There is projecting a plant with a capacity of 100 MW in Jordan (PHOEBUS program) [25].

3.2.1.3. Electrical conversion of the solar energy

Electrical conversion of the solar energy is effected without the passage through the intermediary stadium of the mechanical energy. As follows, the conversion installation well not comprise moving pieces, the system's reliability would be high and the maintenance cost – low. The conversion relies on those three physical effects: thermo-ionic, thermo-electric, photovoltaic. The highest developing degree regarding the technical, technological and commercial aspect has achieved the photovoltaic conversion (PV). Thus, the English magazine "The Economist" of 31 august 1999, has been relating on PV conversion of the solar energy: "Of all alternative energy sources – the wind, the sea waves, the tidal flow, the geothermal - probably the most prospective conversion of solar energy in electrical energy is the photovoltaic one".

The PV cell produced on the basis of a semi-conducting material is the main component of a photovoltaic generator. Under the solar radiation action, there is creating an electric field, which produces positive and negative change carriers that can be separated and collected on the cell's lateral parts. As a consequence, the PV cell is behaving as a continuous current generator. In the terrestrial application, the most commercialized are the PV cells of crystalline and polycrystalline (80%) silicon and the non-crystalline silicon (10%). The industry of photovoltaic electricity is characterized at present as the greatest increase rate. In 2000, the world production of PV modulus increased by 44 % and the settled capacity in the EU Member States by 29 % [26].

3.2.1.4. Priority technologies of solar energy conversion for the Republic of Moldova

The Republic of Moldova is at the beginning in what regards the solar energy use. Taking into account the economic, the social, the substructure of the energy system and the environmental reasons, it is thought that at the first stage of solar sources exploitation, there should be given priority to the following technologies of those mentioned in figures 3.15, 3.16:

- Sanitary water heating, using the plane collector;
- Farm produce drying, using the plane collector with air;
- Water pumping or the small irrigation, using the photovoltaic conversion of the solar energy;
- Utilization of autonomous energy system of isolated and photovoltaic electrical energy for isolated and territorially scattered consumers.

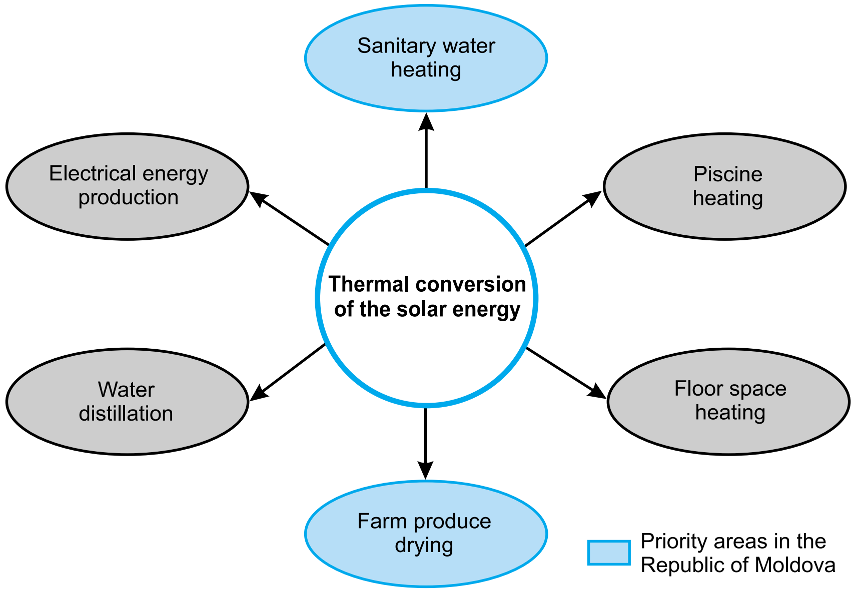


Figure 3.15. Areas of using the thermal conversion of the solar energy.

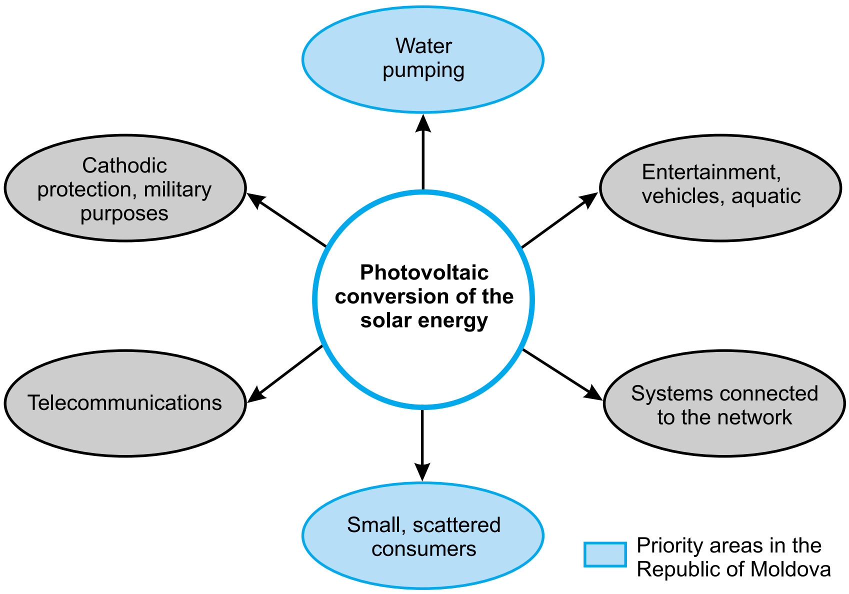


Figure 3.16. Areas of the photovoltaic conversion of solar energy

3.2.1.5. Current status and the usage prospects of conversion technologies of solar energy at European and world level

a) Thermal conversion of the solar energy for water heating

The EU countries objective is to ensure towards 2010, of renewable energy sources about 12 % of the gross internal energy consumption. In 2000 this figure constituted 5,5 %. An important rank in this program is occupied by the thermal solar energy, particularly by plane collectors for water heating. After 1993, there has been stating on annual growth rate of theirs figure of 14 %. If there will be kept the same growth rate, then towards 2010 the total collectors surfaces is estimated to 87 mln m² (*figure 3.17*) [27]. At present, five countries in the world dispose of the greatest number of solar collecting surfaces (*table 3.14*).

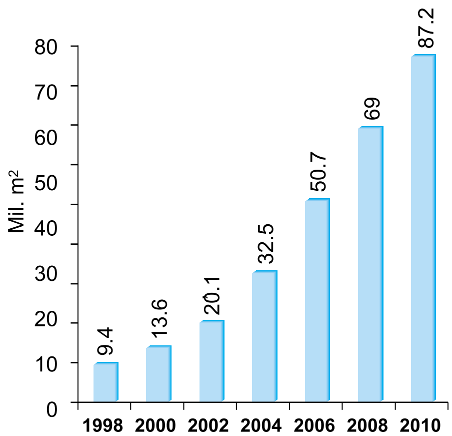


Figure.3.17. Total surface of solar collectors installed in EU Member States

Source: Systèmes solaires. L'observateur des énergies renouvelables. Septembre-octobre 1999, no. 133, mai-juin 2000, no. 137.

Near 2010, two countries of Europe – Austria and Greece – will dispose of about 1 m² of solar collector per capita, that will ensure 60 % of the total warm necessary in Austria and respectively, 75 % - in Greece.

As regards the replacement of fossil sources of energy and the reduction of greenhouse gases (GHG) emissions, there would be achieved the performances included in table 3.15 in the mentioned above countries.

Table 3.14. Surfaces of settled solar collectors (mil m²), in some world states and estimations for 2005 and 2010

Year	USA	Japan	Germany	Greece	Austria
1998	8.9	6.5	2.6	2.5	1.9
2005	NA	NA	17.0	4.9	5.2
2010	NA	NA	55.0	9.8	10.4

Source: Systèmes solaires. Le journal des énergies renouvelables. Septembre-octobre 1999, no. 133.

Table 3.15. Expected results as a consequence of solar collectors implementation for water heating in the respect of the replacement of fossil energy sources and reducing GHG emissions

Country	Solar collector surface, mil. m², 2010	Thermal energy of the solar source	Volume of substituted natural gas, m³/year	GHG emission reductions, t/year
Austria	10.4	$6.0 .10^9$	$6.0 .10^8$	1.4×10^6
Greece	9.8	$7.0 .10^9$	$7.0 .10^8$	1.7×10^6

In the EU states, the solar collectors industry for water heating has achieved a high degree of technological development, continuing to grow, so that in 2000 the number of employees in this field has constituted 15,000.

b) Thermal conversion of solar energy for farm product drying

The solar drying of farm products, one of the oldest technologies of conversion is also the most widespread. Over 2,600 of solar drying plants, of which 800 in EU countries, have been operating at the middle of '90 s in West and Central Europe (*figure 3.18*). The main areas where solar dryers are being used, would be: drying of fodders, cereals, fruits and vegetables, aromatic and medicinal plants. Those 800 solar dryers of EU countries with a collecting surface of 200,000 m^2 allow the substitution of about 1,500 toe of fossil fuel by year and the reduction of GHG emissions by 5,000 t/year [28].

The drying installations are the simplest and the cheapest and in the majority of cases, they can be assembled by the farmer at the destination place.

These are solar collectors with or without greenhouse effect, with natural or artificial ventilation, using a ventilator.

In conformity with the solar radiation effect on products, there are distinguished three types of solar installations [6]:

- Direct;
- Indirect;
- Combined.

In direct installations the solar rays reacts directly on the product, placed on special grills. In order to obtain the greenhouse effect and the product

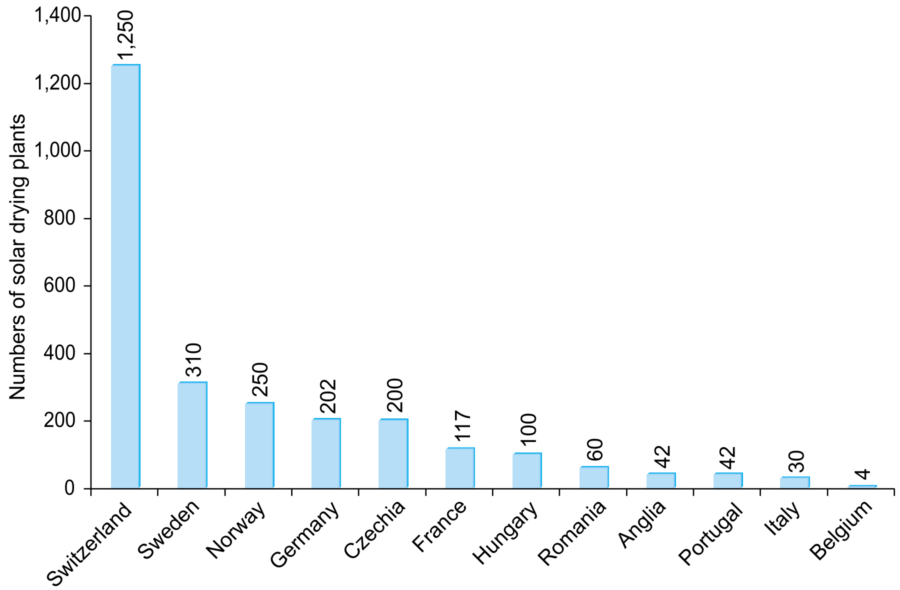


Figure 3.18. Number of solar dryers installed in some countries of Western and Central Europe

Source: Séchage solaire des produits agricoles en Europe. Programme Thermie action nr.SE22, 1996.

protection of the environment (dust, rain, insects, etc.), the grills can be covered with transparent material, usually – film. Direct installations are simple, cheep, but present a range of disadvantages, such as: low efficiency (0.15 – 0.20), low specific productivity (kg/m^2), the impossibility of controlling and managing the process (the temperature and the speed of the drying agent), partial compromising of products as a result of the direct action of solar rays, etc.

Indirect installations, where the drying is performed by conversion, by the help of pre/heated air in solar collectors, are in lack of the majority disadvantages mentioned above. Their main advantage consists in the possibility of avoiding the vitamin degradation in fruits and vegetables, as well as the sensible molecules of medicinal plants.

Combined installations are used for products on which the direct solar radiation does not manifest a considerable action. They have an efficiency and a productivity much more superior to the indirect ones, representing a construction with a transparent roof (sometimes, the walls are also transparent) and a drying room, where is introduced the pre-heated air.

In table 3.16 there are presented the collectors of dryings for agro-food products largely used in European countries [28]. They can be used both for installations with indirect action and with combined one.

The first 4 types can be performed by remaking existent constructions' roofs. The other ones can be reconstructed greenhouses and solariums, which are not exploited during the summer season. The growth of the air temperature in these collectors, conforming to [28] is of 15-20 ^{0}C.

c) Photovoltaic conversion of the solar energy for water pumping and decentralized electricity supply

In 2000 the world PV cells production increased by 44 % and the settled capacity in the EU countries respectively by 29 %. This trend will amplify in the following

Table 3.16. Types of drying installations collectors used in European countries

No.	Collector's construction	Efficiency	Cost $ US/m^2
1	Double roof with a shaft of aspirated air at an edge and recovered at the other one	0.25-0.50	10-30
2	Roof with transparent surface. The roof also serve as a collector	0.20-0.35	20-30
3	Double roof with a shaft of aspirated air through the breaches of the tiles etc.	0.40-0.65	30-50
4	Collector with greenhouse effect and a porous absorber integrated in the roof	0.40-0.60	40-50
5	Collector with greenhouse effect transformed of the solarium	0.15-0.20	4-6
6	Collector with greenhouse effect with a porous absorber transformed of the solarium	0.30-0.60	5-8
7	Collector with greenhouse effect with two lays of film one transparent and the other black	0.30-0.50	5-7

years, as the new national programs involve more and more the great petroleum companies (Shell, British Petroleum) [29, 30].

In figure 3.19 there is represented the evolution of the world production of photovoltaic cells. In the situation in which there would be kept the present rhythm of PV cells production in EU, towards 2010 their total capacity will achieve 1,610 MW.

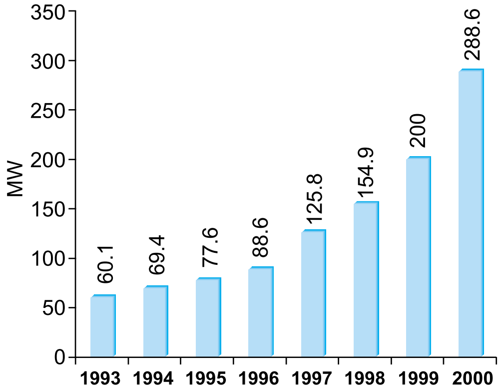


Figure 3.19. The evolution of world photovoltaic cells production

Source: Systèmes solaires. Le journal des énergies renouvelabeles. Mars-avril, no. 136, 2000, Mars-avril, no. 142, 2001

Concomitantly with the growth of the production volume there are decreasing the cost of photovoltaic cells. In table 3.17 there is presented the dynamics cost during 1990-1999. For a period of 10 years the cost of a watt decreased by 2.35 times [29]. In the developing countries there can be outlined two basic domains of using PV electrical energy: water pumping and decentralized electrification. As a relevant example can serve the program financed by EU "Programme Régional Solaire" [31], in conforming to which there have been implemented 1,254 PV installations of which 49 % are destined for water pumping and 51 % - for social and floor space illumination.

Table 3.17. Dynamics of photovoltaic cells cost [33]

Year	1990	1992	1994	1996	1998	1999
Euro/W_c	7.76	6.74	5.82	4.47	3.76	3.3

3.2.1.6. Utilization of solar energy in the Republic of Moldova

The first researches regarding solar energy utilization in the RM have been performed by the Institute of Energy of the Academy of Sciences of RSSM co-workers at the end of '50 s of the last century. At that time, there were elaborated, assembled and tested first solar installations: a solar greenhouse with the heat storage in the soil, two solar installations for water heating in holiday camps of Condrita and Vadul lui Voda. But, as a result of extremely reduced prices practiced for fossil fuel at that period and because of lack of a consistent politics of promoting renewable energy sources, the large-scale implementation of this installation was stopped.

The works for implementing solar installations have restarted in the 80's at the same time with the serial manufacture of solar collectors at several factories of ex-USSR. During 1982-1990, the specialized institutions "Ruralproiect", "Urbanproiect", "Agroprompoiect", have been designed solar installations for water heating in the following objectives; a 4 room house in v. Bucuria; kindergarden for 90 places in v. Harbobet; kindergarden for 90 places in village

Berezchii; hostel for 2,420 places in v. Novoselovca; kindergarden for 160 places in v. Malaiesti; solar drying plant for tobacco in Briceni district and others.

The characteristic of some implemented solar installations during 1982-1990 is presented in table 3.18. These installations were designed, mainly, for water heating in the March-October period. The total collectors' surface was about 12 thousands m^2, fact that allowed the substitution of 1,440 t.c.e. The majority of these installations are no more exploited because of the poor collectors quality, of corrosion and the lack of maintenance works.

Beginning with 1993, in the RM there are producing solar installations for water heating at "Incomas" JSC enterprise. Till nowadays, there have been implemented 140 installations with a total surface of 280 m^2. The characteristic of such installation is presented in table 3.19.

Table 3.18. Characteristic of solar installations implemented in the RM during 1982-1990

Objective's nomination	Solar collector's surface, m^2	Year of fitting
Kindergarden, 160 places village Malaesti, district Criuleni	70	1983
Kindergarden, 180 places village Tescureni, district Ungheni	56	1985
Hostel, 240 places, village Novoselovca, district Orhei	235	1985
APC "Hibrid", "Codru" Sovkhoz	25	1987
"Albota" Sovkhoz	17	1986
"Doina" Sovkhoz	17	1987
MoldNIICS APC "Hibrid"	33	1986
Holiday house "Dnestrovschi"	36	1985
"Inturist" association	5	1985
Auto enterprise of "Struguras" motel	5	1985
"Struguras" motel	85	1985

Table 3.19. List of solar installations implemented by "Incomas" JSC during 1993-2002

Objective's nomination	Number of collectors	Collectors surfaces m^2
The rest house "Luceafarul", Vadul lui Voda	4	5.76
Children camp, village Ivancea	21	30.24
Central market, mun. Chisinau	4	5.76
The textile combine, Tiraspol	32	46
"Santehmontaj" JSC, Edinet	24	34.56
Stone quarry, Soroca	4	5.76
"Autosalubritate" administration, Chisinau	9	19.8
Piscine of the National Institute of Physical Culture and Sports, Chisinau	12	26.4
Place of the Republic, Chisinau	32	46
Auto repair plant, Chisinau	2	2.88

3.2.2. Estimation of the available solar energy potential

3.2.2.1. Methodological aspects of evaluation

For the paramount technologies of solar energy conversion, there has been determined the available energy potential, considering the exploitation period of the solar installations, and the solar radiation features on the RM's territory. Data regarding the solar radiation on a horizontal surface in conditions of medium cloudiness and clear sky were gathered from the State Hydrometeorological Service.

It is known the inclination effect of the solar collector in relation with a horizontal plane, which consists in solar radiation increase, incidental on collector's plane or in the uniformity of the solar energy during the "interested" period. For water heating installations, agro-food products drying and pumping, there have been determined the monthly average values of available solar energy in the related operating periods. With a view to this, there has been used the method described in [32] by J.Duffie and W.Beckman (1991):

1. The global radiation on an inclined plane is determined by the formula:

$$Q_\alpha = R \cdot Q, \tag{3.7}$$

where R is the report between the solar radiation on an inclined plane Q_a and the solar radiation on a horizontal plane Q.

2. If we neglect the solar radiation component reflected from the soil surface, the report R is determined as:

$$R = \left(1 - \frac{D}{Q}\right) R_b + \frac{D}{Q}\left(\frac{1 + Cos\,\beta}{2}\right), \tag{3.8}$$

where D/Q is the ratio between the diffuse radiation and the global one; β collector's angle of inclination reporting to the horizontal surface; R_b – the report between the direct radiation on an inclined surface and the direct radiation on a horizontal surface. It is determined depending on the place's latitude and the inclination angle of tables [32].

3. The D/Q report is determined as following:

$$\frac{D}{Q} = 1.391 - 3.56 K_T + 4.189 K_T^2 - 2.137 K_T^3 \text{ for } \omega_s \le 81.4^\circ,$$

$$\frac{D}{Q} = 1.311 - 3.022 K_T + 3.427 K_T^2 - 1.821 K_T^3 \text{ for } \omega_s \ge 81.4^\circ \tag{3.9}$$

where ω_s is the hour angle of the sunset; K_T – the report between the global monthly average radiation on the terrestrial surface Q and the monthly average radiation Q_o on an extraterrestrial surface. The monthly values of Q are gathered from the State Hidrometeorological Service publications and the Q_o ones from tables presented in [32].

The available solar energy potential on an inclined plane was calculated for different periods of exploitation of the installations. As well, there were calculated the optimal angles of inclinations of collectors or photovoltaic modulus.

As a criterion of optimization, there were chose the maximal values of the solar radiation in the critical months of the exploitation period during which the solar radiation on the horizontal surface decreases. For the photovoltaic installations of pumping, there was considered the fact that they operate effectively only in the hours of sun brightness. The calculation results are exposed in the following paragraphs.

3.2.2.2. Database regarding solar radiation

Data on the solar radiation are available in different forms. The most ample information can be found in publications [33-35]. A systematical description of the RM climate is presented in the monograph [36] based on the meteorological measurements data during 1886-1975. There are described the components of the solar radiation – direct, diffuse and global – on a horizontal surface or perpendicular on solar rays direction and the sun brightness duration. In most of cases the information is presented in the following forms:

- Solar radiation on a horizontal or perpendicular surface in kWh/m^2 or MJ/m^2 for a period of time – on hour, a day, a month;
- Solar momentary radiation or the power density in W/m^2 measured 5 times: respectively at 6:30, 9:30, 12:30, 15:30 and 18:30 in conformity with the solar average time.
- Duration of sun brightness in hours or relative values as the report between the real duration of sun brightness and the theoretical or the possible one.

The information regarding the solar radiations is available for two cases of atmospheres' transparence: in conditions of clear sky (cloudiness 0-3 degrees), which characterize the maximal possible solar radiation and in conditions of medium cloudiness (3-7 degrees).

Figure 3.20. Duration of sun brightness, h/year

Source: Lasse G.F. The climate of the SSRM. Ghidrometeoizdat, Leningrad,1978

3.2.2.3. General description of the solar radiation on the territory of the Republic of Moldova

The quantity of solar energy received on the earth surface depends on a range of factors and, firstly on the duration of sun brightness and the sun's height above the horizon. In the RM the possible duration (theoretical) of sun brightness is 4,445-4,452 h/year. The real duration constitutes 47-52 % or 2,100-2,300 h/year (*figure 3.20*) of the possible one. The variation of above 5 % is due to the difference of latitude between the North zone and the South one, which is about 2.5 %. A considerable part of the sun bright ours correspond to the months of April-September, constituting 1,500-1,650 hours. The global radiation (the sun of direct and indirect radiation) on a horizontal surface in conditions of medium cloudiness constitutes 1,280 kWh/m² year in the North zone and 1,370 kWh/m² year – in the South zone (*figure 3.21*). Over 75 % of this radiation correspond to April-September months. The global radiation in the North zone is smaller by 3.5 % that in the Central zone and bigger by 2.6 % in the South zone. The insignificant difference between these values allows us to use in the following calculations data on solar radiation for the Central zone of the RM, meaning meteorological measurements data performed at the Chisinau station.

In table 3.20 are presented diurnal and monthly values of the global radiation and of sun brightness duration on a horizontal surface in the central zone of the RM in conditions of medium cloudiness.

Figure 3.21. Annual values of the global solar radiation, kWh/m² year

Source: Lasse G.F. The climate of the SSRM. Ghidrometeoizdat, Leningrad,1978

Table 3.20. Global radiation on a horizontal surface in the Central zone of the RM and the duration of sun brightness, conforming to [35]

Month	Diurnal radiation, kWh/m² day	Monthly radiation, KWh/m² month	Duration of sun brightness, h/month
I	1.1	35	72
II	1.6	46	75
III	2.7	84	133
IV	4.3	129	190
V	5.4	164	246
VI	6.4	192	291
VII	6.1	189	312
VIII	5.3	164	294
IX	4.1	123	230
X	2.5	78	165
XI	1.1	33	69
XII	0.8	25	55
Total per year	–	*1,265*	*2,132*

3.2.2.4. Available energy for water heating installations

The assessment is based on data gathered from [33], using the calculation method exposed in p.3.2.2.1, considering the specific features of the used technique, particularly the exploitation period during the year, the angle of inclination of the collectors of PV modulus, the contribution of the solar radiation. In the practice of projecting systems of solar energy conversion there are used monthly data on solar radiation, more seldom – the diurnal or hourly ones, because the calculation volume increases considerably.

The efficient yearly operation period of water heating installations constitutes about 7 months: the period of 15 March – 15 October. As largler is the operation period of the water heating installations during a year, thus will be greater its efficiency. With a view to this, it has been determined the optimal angle of inclination taking as a criterion of optimization the solar radiation in March and October. The related results are presented in table 3.21, 3.22 and figures 3.22 and 3.23.

We state that for an inclination angle $\beta = 40^0$ the global solar radiation increases in March by 21 %, in October – respectively by 50 % and in July decreases by 10 %. Although there is not stated a significant growth of the solar radiation for the entire period March-October (table 3.22), it counts a lot the increased solar radiation of March and October, thus ensuring the minimal necessary of warm water in these months.

Table 3.21. The R report between the global radiation on an inclined plane and a horizontal plane for March, July, October

Degrees	0	15	20	25	30	35	40	45	60	90
R_{III}	1	1.12	1.15	1.19	1.20	1.20	1.21	1.20	1.14	0.85
R_{VII}	1	0.99	0.99	0.97	0.95	0.93	0.90	0.82	0.72	0.38
R_X	1	1.24	1.32	1.38	1.42	1.46	1.50	1.52	1.52	1.26

Table 3.22. Monthly average solar radiation in March-October period. The inclination angle is equal to 40^0. The case of water heating systems

Month	III	IV	V	VI	VII	VIII	IX	X	III-X
Q_0, kWh/m^2	84	129	167	192	189	167	123	78	1,129
Q_{40}, kWh/m^2	102	135	154	169	170	167	146	116	1,159

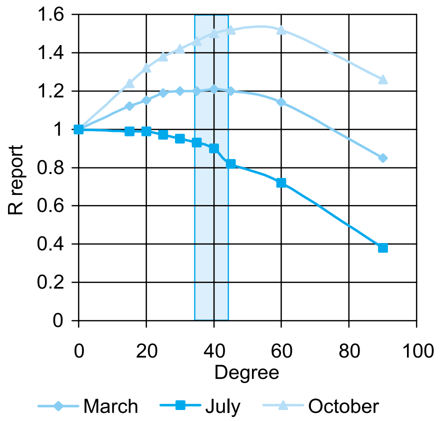


Figure 3.22. The ratio R report between the global radiation on an inclined plane and on a horizontal one. Case of solar installations for water heating

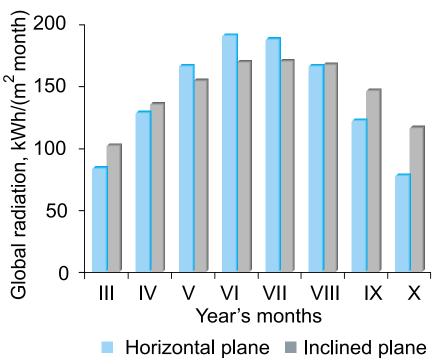


Figure 3.23. Global radiation for the March-October period. The case of water heating installations. The inclination angle is 40^0

3.2.2.5. *Available energy for plants installations of drying fruits, vegetables and medicinal plants*

The implementation in the RM of solar drying plants would allow not only the saving of fossil sources of energy and the GHG emissions reduction, but also the avoidance of fruits and vegetables losses due to the rapid conservation at the production place. The exploitation period of these installations coincides with the maximal solar radiation period and lasts usually in the May-October interval. One and the same installation can be used for drying medicinal plants, fruits and vegetables, wastes resulted from the agricultural produce processing. In such a case, it would be rational to dispose of more solar energy in September and October. Thus, it was calculated the angle of inclination for which is ensured a greater global radiation in the related months. For an angle of 35 degrees, the global radiation will be greater by 20 % in September and by 46 % in October. The calculation results for this case are included in tables 3.23 and 3.24 and in figures 3.24 and 3.25.

Table 3.23. The R ratio between the global radiation on an inclined plane and a horizontal plane for May, September, October

Month	V	VI	VII	VIII	IX	X	V-X
Q_0, kWh/m^2 month	167	192	189	167	123	78	916
Q_{35}, kWh/m^2 month	159	175	176	171	146	113	940

Table 3.24. Monthly average solar radiation for the March-October period. Inclination angle β=35^0

Degree	0	15	20	25	30	35	40	45	60	90
R_{IV}	1	1.09	1.1	1.11	1.12	1.11	1.09	1.06	0.97	0.61
R_{VII}	1.0	1.0	0.99	0.98	0.95	0.93	0.90	0.82	0.72	0.36
R_{IX}	1.0	1.16	1.22	1.22	1.24	1.25	1.26	1.25	1.18	0.84

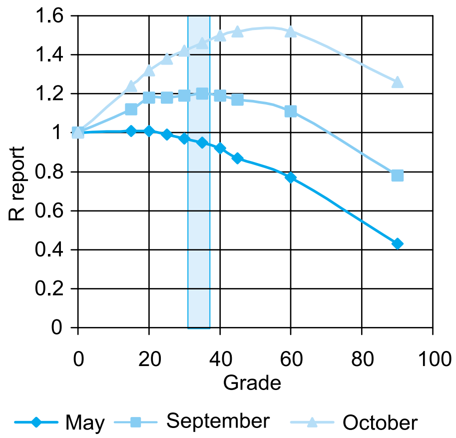


Figure 3.24. The ratio R between the global radiation on an inclined plane and on a horizontal one. Case of solar drying plants

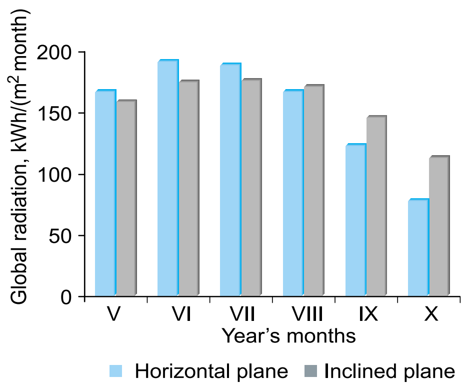


Figure 3.25. Global radiation for the March-October period. The case of drying plants. The inclination angle is 35°

3.2.2.6. Available energy for photovoltaic pumping stations

Unlike the thermal solar plants, the pumping installations without electrical energy accumulators, operate only in conditions of clear sky, meaning if there exists direct radiation. This feature imposes an other modality of assessing the available solar radiation. From solar radiation components: global Q, direct S and diffuse D on a horizontal surface in conditions of clear sky, as well as the relative values of the real durations of sun brightness. Multiplying the indexes of the sun brightness duration it is obtained the available radiation value on a horizontal surface only for these time periods. As follows, it is determined the solar radiation on an inclined plane in conformity with the Liu-Jordan model [32]. The results are included in tables 3.25, 3.26 and in figure 3.26 and 3.27.

We state that the useful values of the solar radiation are smaller than in the previous cases, because there were countered only the real hours on sun bright.

Table 3.25. The ratio R between the global radiation on an inclined plane and a horizontal plane for April, July and September

Degree	0	15	20	25	30	35	40	45	60	90
R_{IV}	1	1.09	1.1	1.11	1.12	1.11	1.09	1.06	0.97	0.61
R_{VII}	1.0	1.0	0.99	0.98	0.95	0.93	0.90	0.82	0.72	0.36
R_{IX}	1.0	1.16	1.22	1.22	1.24	1.25	1.26	1.25	1.18	0.84

Table 3.26. Monthly average solar radiation for the March-October period. Inclination angle β=25°.

Month	IV	V	VI	VII	VIII	IX	IV-IX
Q_0, kWh/m^2 month	93	127	153	158	140	96	767
Q_{25}, kWh/m^2 month	102	127	147	155	149	117	797

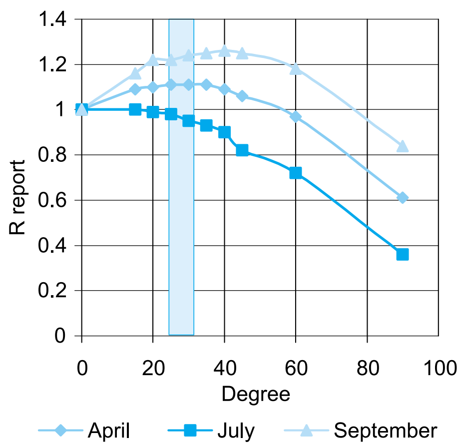


Figure 3.26. The ratio R between the global radiation on an inclined plane and on a horizontal one. Case of PV pumping systems

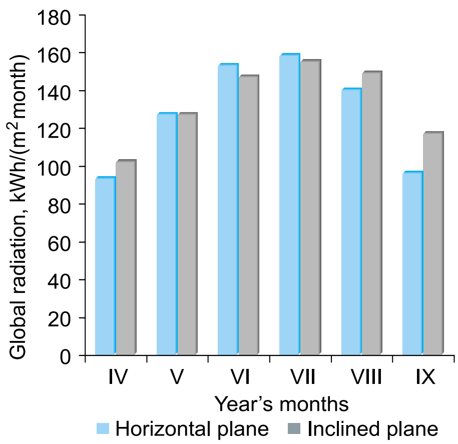


Figure 3.27. Global radiation for the April-October period. The case of PV pumping installations. The inclination angle is 25°

3.2.3. Demand assessment of thermal and photovoltaic solar energy

3.2.3.1. Methodology of energy demand evaluation for water heating in the rural area

In order to determine the seasonal heat consumption, for water heating on the entire the RM territory, it was decided to use the notion of average consumer of thermal energy and of specific average norm of thermal energy for the following consumption categories:

- Floor space (houses and flats);
- Schools;
- Kinder gardens;
- Medical institutions: hospitals, polyclinics, health-obstetric service;
- Public baths;
- Servicing enterprises;
- Public alimentation enterprises: worker's restaurants, bars, café's etc.;
- Sport objectives: stadiums, piscines, physical training clubs;
- Hotels, tourist camps.

There were examined three Counties of different the RM zones:

- North – County Balti;
- Center – County Lapusna;
- South – Territorial Administrative Unity-Gagauz Yeri(TAUG).

The season duration of the water solar heating constitutes 214 days: from 16 March – till 15 October. The number of working days in this period for different consumption categories constitutes:

- Houses, apartments, hospitals, hotels – 214 days;
- Schools - 97 days, as a vacation being considered the 15 June - 1 September interval, the working week having 5 days;
- Kinder garden, polyclinics, health-obstetric services – 153 days, the week having 5 working days;
- Baths, servicing enterprises, workers' restaurants, bars – 183 days, the week having 6 working days.

In order to determine the thermal energy consumption for water heating there are necessary the following data:

- Specific norms of heat water for different categories of consumers;
- Number of consumers distributed by categories;
- The temperature of heat and cold water, duration of solar energy using season for water heating, available solar energy potential.

The specific consumption values of heat water for different categories of consumers were adopted in conformity with the current corms [37], with some explanations, which result from the world practice of exploiting similar systems [38]. For calculations there were used the following heat water norms for a person (considering different consumption categories):

- Houses, apartment – 50 l/day;
- Schools – 3 l/day;

- Kinder garden – 10 l/day;
- Hospitals – 50 l/day;
- Policlinics and obstetric services – 5 l/day;
- Baths – 100 l/day;
- Public alimentation enterprises – 6 l/day;
- Barber's – 30 l/day;
- Stadiums – 30 l/day;
- Hotels – 50 l/day.

Data regarding the number of consumers on categories for each locality of the examined districts were gathered from: Statistical dictionary of Moldova. Special edition in 4 volumes. Statistical Department of the Republic of Moldova, Chisinau, 1994 [39], where are presented information on:

1. Locality's population;
2. Social substructure;
   - The number of houses or apartments and their surface;
   - Dwelling fund endowment with centralized heating, heat water, piping natural gas or liquid gas.
3. Number of workers' restaurants, cafés, bars, etc.;
4. Medical institutions: hospitals, polyclinics, health-obstetric services;
5. Schools, kinder gardens;
6. Hotels, sport objectives and tourist centers.

Data from this dictionary were up/dated in conformity with [40] and those relating to new localities gasification during 1992-2000 – conforming to the information presented by Moldova-Gas JSC

Supplementary, there were utilized the following average data specific for the RM:

- The number of children in kinder gardens for the rural zone is considered equally to 10 % of the locality's population [40];
- Occupied places in hospitals – 70 % of the number of beds [41];
- Visits at polyclinics and obstetric services – 5 of each person by season [41];
- Bath visits – 1 by week, number of visitors – 30 % of locality's population.
- Visits at the servicing units – 1 by month for each inhabitant;
- Occupied places in public alimentation units – 50 % of the total, program – 8 h/day;
- Stadiums are frequented by 20 persons, 3 times a week;
- Usage indexes of hotels accommodation capacity – 20 % [41].

The average temperature of the cold water at the entrance in the collector is considered equal to 10 ^{0}C and the heat water temperature – of 55 ^{0}C. the solar energy available potential was determined in paragraph 3.6.

By these data help there were calculated the specific average sizes for the examined districts, reported at a thousand inhabitants for the above indicated categories of consumers, the specific consumption of thermal energy (GJ per capita) for each category and the total average by categories and by districts. The results for the examined districts have been extrapolated on the other districts, on the basis of their population. Thus, it has been determined the thermal energy demand for water heating in the RM's rural sector. As follows, it has been calculated the total surface o solar collectors, the quantity of substituted energy sources, the foreseen GHG emissions reductions.

3.2.3.2. Specific characteristics of the examined districts

The examined districts differ considerably by the number of localities, population number in each locality and the number of a family members (number of inhabitants in a house) – at North localities are smaller and the families less numerous. In the table 3.27 there are presented the related information.

In table 3.28 is presented the characteristic of examined districts by categories of consumers, excepting the dwelling one. The related indexes are reported to a thousand of inhabitants.

The specific consumption of calculated thermal energy, in GJ/per capita for all consumption categories and in total on all examined districts is presented in the table 3.29.

We state that for the examined districts, the deviation, of the total thermal energy consumption of the average value do not overrun 1 % (*table 3.29*). Although for some categories of consumption there exist a considerable deviation, for example, sport objectives, hotels and tourist centers, these do not influence significantly the total specific consumption, because their weight in the global thermal energy consumption is insignificant and do not exceed 1 % (*figure 3.28*). The greatest weight belongs to the dwelling sector – 85,6 %, followed by communal baths by 7,4 %.

The thermal energy demand distribution in the social and communal sectors is presented in figure 3.29, of which it is stated an acceptable uniformity of the

Table 3.27. Characteristic of the analyzed districts

County	Number of localities	Population	Inhabitants in a house
Balti	245	348,638	2.71
Lapusna	152	285,061	3.20
TAUG	32	163,795	3.62
Average			*3.15*

Table 3.28. Counties' characteristic on categories of consumers. (The indexes are reported to a thousand of inhabitants)

Index	Balti	Lapusna	TAUG	Average
Pupils	202.2	219.2	197.3	207.3
Kinder gardens, units	0.75	0.73	0.62	0.71
Medical institutions, visits plus beds	12.2	13.8	16.2	14.1
Baths, units	0.43	0.34	0.18	0.35
Servicing enterprises, units	0.34	0.33	0.25	0.32
Public food enterprises, places	26.3	29	34.1	29.2
Sport objectives, units	0.26	0.36	0.11	0.27
Hotels and tourist centers/camps, units	0.017	0.049	0.043	0.034

Table 3.29. Thermal energy consumption for different categories of consumers, GJ/per capita

Consumption categories	Specific consumption of thermal energy			
	Balti	Lapusna	TAUG	Average
Residential sector	2.017	2.017	2.017	2.017
Schools	0.011	0.012	0.011	0.0113
Kinder gardens	0.0288	0.0288	0.0288	0.0288
Medical institutions	0.0151	0.0162	0.0207	0.0173
Baths	0.175	0.175	0.175	0.175
Servicing enterprises	0.0394	0.04	0.04	0.0394
Public food enterprises	0.0218	0.0248	0.0282	0.0249
Sport objectives	0.0274	0.0038	0.0011	0.0108
Hotels, tourist centers	0.0254	0.0052	0.0076	0.0127
Total	*2.361*	*2.323*	*2.329*	*2.338*

energy demand for the examined districts. As follows, although there exist a certain difference in the thermal energy demand of some categories of consumers in different zones of republic, there can be accepted the average values which characterize those three counties of different RM zones. These features are:

1. Conventional number of persons in a house (apartment) – 3.15;
2. Thermal energy specific demand per capita by season for different categories of consumption, constitutes:
   - Residential sector – 2,017 MJ;
   - Schools – 11,3 MJ;
   - Kinder gardens – 28,8 MJ;
   - Medical institutions – 17,3 MJ;
   - Baths – 175 MJ;
   - Servicing enterprises – 39,4 MJ;
   - Public alimentation enterprises – 24,9 MJ;
   - Sport objectives – 10,8 MJ;
   - Hotels, tourist centers – 12,7 MJ.
3. Total specific average demand per capita constitutes 2,338 MJ.

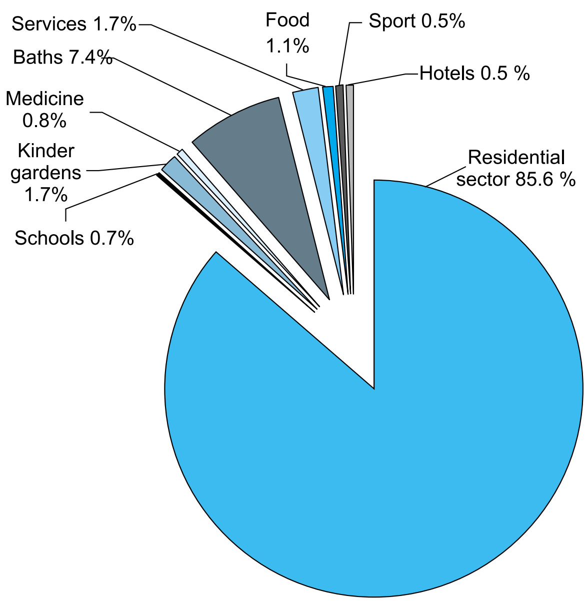


Figure 3.28. Breakdown of thermal energy demand

The dwelling sector is the greatest thermal energy consumer. Total energy demand for water heating in this sector represents 5.34x10^6 GJ.

3.2.3.3. *Total surface assessment of solar collectors for water heating in the rural sector*

The most usual conversion installations of solar energy into thermal energy, having as a goal heat water production are plane collectors with a single transparent surface. Using the assessed data of solar radiation of 3.2.2 paragraph and data on monthly average temperatures, there have been determined of solar collector's characteristic for the operating period (16 March – 15 October). The optimization criterion: the maximal collected thermal energy during the operating period. There resulted the following characteristic:

- The optimal collectors angle of inclination – 35°-40°;
- Average efficiency for the operation period – 0.4;
- Useful thermal energy for the operating period – 1.623 GJ/m^2;

These data, as well as the data regarding the thermal energy demand presented in the paragraphs 3.2.3.1 and 3.2.3.2, there were put at the base of calculations of the solar collectors' necessary surface area for all mentioned above categories of consumption. The obtained results were included in the table 3.30.

3.2.3.4. *Assessment of thermal energy demand for drying fruits, vegetables and medicinal plants*

The calculation of thermal energy demand for drying food products is performed on the basis of data on initial and final humidity, consumption of raw material, thermal agent temperature, efficiency of the process and dried product volume.

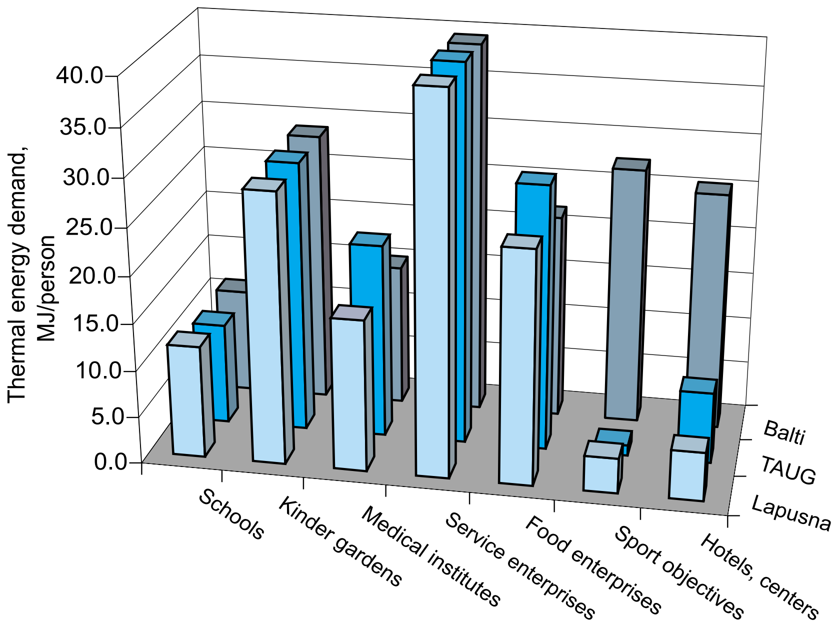


Figure 3.29. Thermal energy demand distribution on categories of social and communal consumption

Table 3.30. Surface area of solar collectors for water heating

Consumption categories	Operation period, days	Area	
		Specific, m^2/per capita	Total, thousands m^2
Residential sector	214	1.2	3,175.4
Schools	97	0.015	39.2
Kinder garden	153	0.024	63.4
Medical institutions	183	0.012	31.8
Baths	183	0.122	322.2
Servicing enterprises	183	0.028	73.3
Public food enterprises	183	0.017	45.8
Sport objectives	31	0.045	119
Hotels, tourist centers	214	0.008	20
Total			*3,890.2*

Data on initial and final humidity of different agro-food products are presented in table 3.31.

For estimative calculations we acknowledge the following average parameters of the drying process:

- Initial humidity – 80 %;
- Final humidity – 15 %;
- Air average temperature in summer days – 22 °C;
- Air average temperature warmed up in collectors – 40 °C;
- Relative air humidity – 60 °C;

Table 3.31. Humidity of fresh and dried agro-food product

Product	Information source	Water content, %	
		Initial	Final
Fruits	[28]	50-80	15
	[49]	73-88	16-20
	[50]	80-85	16-30
Vegetables	[28]	50-80	15
	[49]	65-88	7-14
	[50]	61-95	8-10
Medicinal plants	[28]	80	15

The characteristic of the drying process, calculated for air and products acknowledged parameters, are described in table 3.32.

In table 3.33 there are exposed statistical data [40, 42] on global fresh and dried fruits production and medicinal plant export. Statistical data on medicinal plants and dried vegetables production are missing.

For assessment calculations we acknowledge the following values of annually dried products:

Table 3.32. Technological values of the drying process of food products

Process characteristic	Value
Row material consumption, kg/kg	4.25
Evaporated water quantity, kg/kg	3.25
Process efficiency	0.6
Air feed, m^3/kg	680
Energy consumption, MJ/kg	16.25

Table 3.33. Production and drying fruits potential and medicinal plants export

Year	Fresh and dried production		Medicinal plants export, tons
	Fresh, thousands t	Dried, thousands t	
1997	947	1.23	231
1998	367	0.44	290
1999	136	0.37	259
2000	255	0.55	145

- Fruits – 600 t;
- Vegetables – 100 t;
- Medicinal plants – 450 t.

Launching the hypothesis that 50 % of the total production will be obtained using solar energy, the necessary thermal energy quantity will be $7.5x10^6$ MJ or 260 t.c.e. In order to obtain this quantity of energy there are necessary about 5,000 m^2 of solar collectors that will operate during the period May – October, with an average efficiency of 50 %.

3.2.3.5. Consumers identification and assessment of photovoltaic electricity demand

At present, there is stated an accelerated development of the decentralized rural electrification in developing countries (DC) based on the use of solar energy [31]. Although the photovoltaic (PV) technology is considered expensive, the world production growth rate of photovoltaic cells in 2000 constituted 44 % [30]. Why do not DC cross the same way the European industrialized countries did in the electrification field? The reasons that limit the application of the traditional solution – thermal conversion of fossil fuel into electrical energy and its distribution by networks – are the following:

- The majority of rural consumers of electrical energy are situated at considerable distances from the existent electrical networks, having a poor density;
- The electrical energy demand is small and is comprised in the limit of 10-20 kWh/day;
- Usually, the electrical energy is used for lightening, telecommunications and for operating small-motorized installations: electrical pumps, workshop tools, etc.

In these conditions, the traditional electrification presents an inefficient solution both from economic and environmental points of view. Thus, investments and operating expenses, the calculated GHG emissions per capita, are increasing as the efficiency of transportation and distribution of one kWh of electrical energy is reducing.

The Republic of Moldova also has a DC status, but the electroenergetical substructure differs from the existent one in DC of Asia and Latin America.

The population density and therefore the electricity consumers density that corresponds to each kilometre of electrical network is much more intense. The absolute majority of rural localities, or economic units are connected to the public electrical networks and it would seem that the arguments above cannot be available also for our country. But the performed studies in the last years [31] prove the existence of hundreds small electrical energy consumers territorially dispersed, for which the single rational solution is the one offered by the PV technology. We will mention here only two categories of such consumers: water-pumping installations for small irrigation and the launching station antihail rocket.

By the RM Government Decision no.256 of 17.04.2001 "On the irrigation systems' rehabilitation", there was approved the Rehabilitation program of irrigating systems for the period of 2001-2008. According to this program, it is foreseen the irrigation of small surfaces of 1-10 ha. The total capacity of small irrigation constitutes 36 thousands ha or 22 % of the total irrigable surface of about 160 thousands ha. As water sources there can serve those 3,000 water accumulations of which 411 are more important. The repartition of irrigable surfaces on Counties within the Development program of the small irrigation is presented in table 3.34.

In order to assess the number or potential consumers of photovoltaic electrical energy there have been analyzed statistical data on the vegetables production in farm enterprises (FE) [40, 41]. In 2000 the total number of FE constituted 131.6 thousands, having in their possession 285.4 thousands ha of agricultural land or in average by 2.2 per FE. The vegetables production in FE constituted 87 thousands tons or 24 % of the total production on the country, being obtained of a surface of 12.6 thousands ha. If we would admit that all the 2.2 ha surfaces were sown with vegetables, we would obtain the minimal number of FE – 5,700 – that need water for irrigation. According to a sociological study performed in August 2001 by NGO "AGROinform National Federation" in collaboration with "Contact" Center, about 23.5 % of FE of the questioned specialized ones themselves in harvesting. Thus, the real number of water consumers for irrigation can be 5-6 times greater.

Table 3.34. Surfaces of small irrigation and the water volume by districts

County	Irrigable surface, ha	Water volume, thousands m^3
Chisinau	7,080	14,160
Orhei	4,900	9,800
Edinet	4,650	8,300
Soroca	4,210	8,420
Tighina	3,800	7,600
Taraclia	3,100	6,200
Lapusna	3,020	6,040
Balti	2,630	5,260
Ungheni	1,290	2,480
Cahul	850	1,700
TAUG	500	1,000

Source: Rehabilitation program of irrigating systems for the period of 2001 – 2008, Governement Decision no. 256 of 17.04.2001

The RM antihail service comprise 150 antihail rocket launching stations and 12 stations – control centers – which are endowed also with recharging equipments for accumulators. From security reasons, the antihail stations are placed at a distance of 2-3 km from locality's borders.

Table 3.35. Number of consumers and PV electrical energy demand

Consumers	Number of consumers	Electrical energy demand kWh/season	PV Modulus power, kW_c
Small irrigation	5,700	$3.2 \cdot 10^6$	6,300
Antihail service	150	2,800	7.5

An average distance between the antihail station and the Control center is about 50 km. Because the electrical energy consumption at an antihail station is low (about 0.15 kWh/day), their feeding from the public electrical networks is not economically justified. At present, the electrical energy supply of consumers of antihail stations is performed from accumulators. Periodically, accumulators are recharged at the nominated Control Center, which serves 12-15 stations. Thus there is consumed a significant liquid fuel quantity (petrol or diesel oil) for transportation. The active exploitation period of the antihail stations comprise the April – September months and coincides with the maximal radiation period in the RM. The PV modulus usage for accumulators recharge directly to the station, reduces considerable the liquid fuel consumption, the number and accumulators' capacity.

Thus, the minimal number of potential users of PV electrical energy in these two sectors - small irrigation in FE and antihail stations – counts to 5,850.

It's well known the fact that irrigation contributes to the crops increase by 2-4 times. Thus, in order to get a quantity of vegetables that was harvested in 2000 there will be necessary a surface of only 6,300 ha. In table 3.35 are presented the results of calculations relating to the PV electrical energy demand and the photovoltaic models power in the following terms: efficiency of the pumping aggregate – 32 %, of PV modulus – 14 %, irrigation norm – 2,000 m^3/ha.

3.2.4. Assessment of costs and economic benefits as a consequence of solar energy implementation

3.2.4.1. Cost-benefit analysis of solar stations for water heating

1. Residential sector

The economic efficiency estimate of investments in solar plants for water heating was performed on the basis of net present value (NPV) [6] that was determined depending on the annual net income and the discounted study period. It was acknowledged that the study period is equal to the installation life-time period – 20 years in some sources there is considered that the related period can rise up to 30 years [43], and the discounting rate – 10 %. For these conditions the discounted period constitutes 8.51 years. The annual net income was calculated as the difference between the gross annual income and total annual expenditures. The thermal energy cost substituted by solar installation is found in calculations as gross annual income. Because the conventional plants, which produce the heat water on the basis of certain fossil sources (kettles, boilers, cooking stoves) are already assembled and will operate during the year's outstanding period and some of them also during the research period for other purposes (for example, cooking stoves), the thermal energy cost, produced by conventional installations did not include the investments in their construction, this one being composed of the fuels cost and of expenses connected to the related plant's exploitation (5-10 %). The characteristics of the substituted sources and their costs are presented in table 3.36.

Table 3.36. Caloric capacity and the cost of fossil energy resources

Substituted source	Caloric capacity	Specific cost
Natural gas	33.2 MJ/m^3	0.08 USD/m^3
Liquified gas	55.1 MJ/kg	0.50 USD/kg
Coal	22.6 MJ/kg	0.07 USD/kg
Electrical energy	–	0.05 USD/kWh

There have been analyzed installations for houses in which inhabit a different number of persons. The constructive parameters, the cost of installations and solar thermal energy are presented in table 3.37. It is stated that at the same time with the increase of the number of inhabitants in a house, the specific cost of installation decreases. Thus, for a conventional family of 3.15 persons, the installation's specific cost will be 143 $ USA/m^2. for the total collectors surface of 3.175 mil m^2 the required investments will constitute 454 mln $ USA. The cost of solar thermal energy for a conventional house is 4.85 $ US/GJ or considering the exchange rate of 13 MDL/1 USD – 265 MDL/Gcal. The calculations results are presented in figure 3.30.

In table 3.38 are presented the NDI values for a conventional person (of a conventional family of 3.15 members). For the existent prices, the substitution

Figure 3.30. Net present value depending on the number or persons in a house and the substituted energy resource

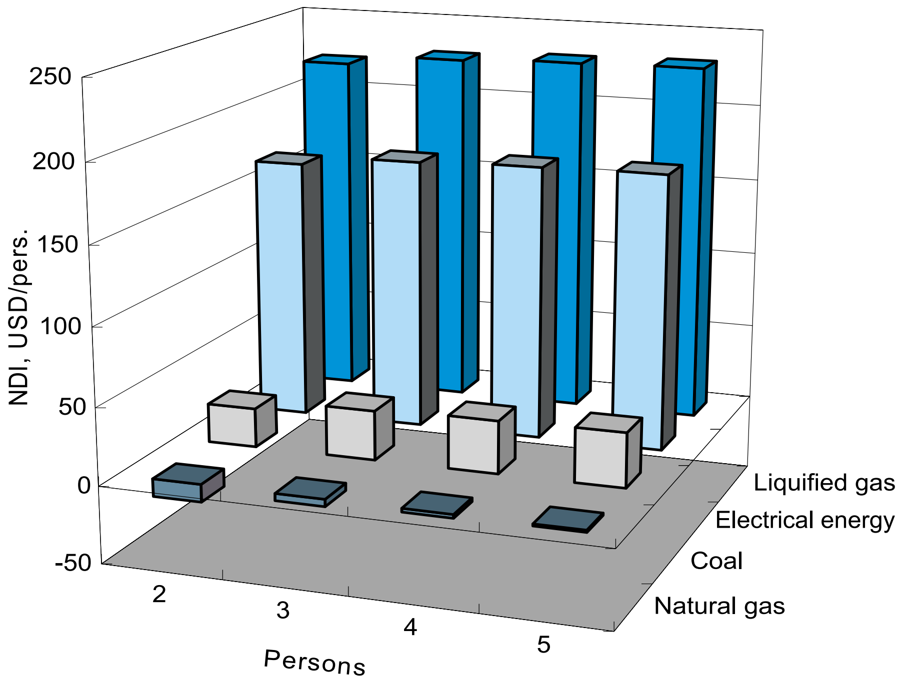


Table 3.37. Constructive parameters, solar installations cost, cost of solar thermal energy

Number of persons in a house	**2**	**3**	**4**	**5**
Collector's surface, m^2	2.4	3.6	4.8	6
Collector's cost, USD	168	252	336	420
Water reservoir volume, l	200	300	400	500
Reservoir cost, USD	75	100	125	150
Pipe length, m	20	20	25	30
Pipe cost, USD	30	30	37.5	45
Armour cost, USD	10	10	10	12
Assembling works quote in the cost, %	20	20	20	20
Total installation cost, USD	374	517	671	828
Specific cost, USD/m^2	156	144	140	138
Annual depreciation, USD/year	18.68	25.87	33.56	41.38
Annual operation and maintenance cost, %	10	10	10	10
Total annual cost, USD	20.55	28.46	36.92	45.52
Thermal energy production, GJ/year	3.89	5.83	7.78	9.72
Cost of solar thermal energy, USD/GJ	5.28	4.88	4.75	4.68

of fossil energy sources for heat water production with solar energy is not efficient from the economic point of view only for the natural gas.

Table 3.38. Net discounted income (NDI) at the substitution of fossil sources with solar energy

Substituted source	**NDI, USD/per capita**
Natural gas	-4.48
Liquified gas	228.55
Coal	32.16
Electrical energy	174.79

2. Communal baths

As a research object it was acknowledged a bath of 284-4 I.5.86 type, of 20 places. For calculations there were accepted the following initial data:

- Occupancy of places degree – 0.75;
- Duration of working day – 8 h;
- Operating days of the bath during the season – 92 (3 days by week);
- Operating days of collectors' season – 153 (5 days / week);
- Duration of a visit – 1 h;
- Water norm for a visitor – 100 l.

The solar collectors area is 77 m^2 and the water circulation is forced. The daily water consumption constitutes 12 m^3. In order to ensure the heat water storage during a week, there is chose a reservoir with a capacity of 36 m^3 (4x3x3 m). The specific cost of the equipment is the same as in the previous case. The total cost constitutes 8,450 USD, the specific cost of a square metre of collector being 110 USD/m^2.

The annual heat production is 207.5 GJ, the thermal energy cost – 3.86 USD/GJ. The objective's unitary thermal power is relatively strong – 66 kW. For comparison there has been accepted as a conventional source of thermal energy a boiler that operates on natural gas, coal or diesel oil. The net present value reported to a conventional consumer, depending on the substituted energy, is presented in figure 3.31. At the natural gas substitution there take place insignificant losses. In exchange, the substitution of the other fuels will have a substantial income – over 1,500 USD in case of coal and over 10,000 USD in the diesel oil case.

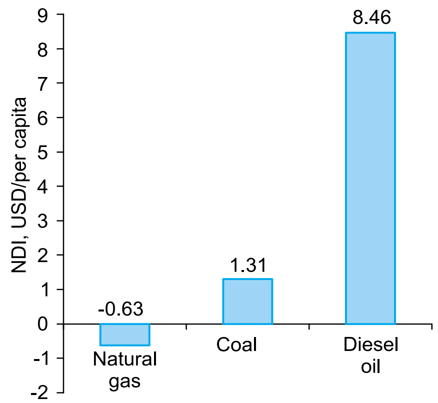


Figure 3.31. Net present value obtained as a result of fossil fuel substitution at a communal bath

3. Kinder garden

For the study there has been acknowledged a kinder garden of 160 places conforming to the project of 215-1-137-C type. The objective is composed of 5 bodies joint by galleries. The plant will be placed on the flat roof on clamps, the circulation of the thermal agent being forced. The installations parameters are:

- Collectors' surface – 25.5 m^{2};
- Heat water consumption – 1.2 m^3/day;
- Reservoir volume – 2 m^3;
- Thermal power – 6.6 kW;
- Thermal energy productivity by season – 41.3 GJ;
- Total investments – 2,658 USD;
- Specific cost – 104.2 USD/m^2;
- Solar thermal energy cost – 3.66 USD/GJ.

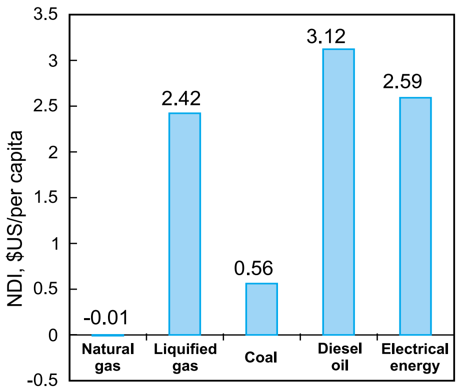


Figure 3.32. Net discounted income obtained as a result of fossil fuel substitution at a kinder garden

In order to meet the present demand of heat water, kinder gardens are using different installations on the basis of conventional sources: cooking, stoves, boilers, electrical boilers etc.

The NPV depending on the substituted energy is presented in figure 3.32. As in the previous cases, the piping substitution is inefficient.

3.2.4.2. Cost-benefit analysis of solar installations for drying fruits, vegetables and medicinal plants

1. Installations for drying fruits and vegetables

For drying fruits and vegetables there is used a combined plant with walls of transparent film on a wood carcass. The air circulation in the plant is natural. The plant's technical and economic indexes are presented in table 3.41. In the indicated collectors' area is included only the inclined to south surface. The average duration of a during cycle is 10.2 h. the installation's carcass is made of wood and has a life-time period of 5 years, the film being replaced every season. The drying season period was considered 80 days with a usage degree of the installations of 0.7.

2. Installation for drying medicinal plants

For the feasibility study we acknowledge a installation with indirect action with a solar collector of type 3 (table 3.16). The basic indexes of the installation are presented in table 3.40. The installation's efficiency include the drying process efficiency, collectors efficiency and the coefficient of heat keeping in the drying room. The installation cost comprise also the building cost under the roof – collector, a part of which is occupied by the drying room and the ventilator and the other one can serve as a storehouse or can have any other destination. The lifetime period of the installation is 20 years, with a repair expenses quota of 15 % of its initial cost. The period of the drying season is equal to 100 days with a usage degree of the installation of 0.6. The exploitation expenses are equal to 10 % of the total annual expenses. The economic indexes of the installation are presented in table 3.41.

Table 3.39. Technical and economic indexes of the fruits and vegetables drying plant

Indicators	Units	Value
Installation's productivity	kg/season	1,800
Charge of row material	kg/cycle	144
Collector's area	m^2	24
Installation's efficiency	–	0.5
Installation's cost	USD	410
Raw material consumption	t/season	8.0
Raw material cost	USD	150
Total annual cost	USD	1,450
Selling price of production	USD /kg	1.0
Net annual value	USD	370
Net present value	USD	3,460

Table 3.40. Indexes of installation of drying medicinal plants

Indicators	Units	Value
Productivity	kg/cycle	170
Collector's area	m^2	42
Cycle duration	days	5
Installation's efficiency	–	0.3
Ventilator's productivity	m^3/h	3,500
Ventilator's power	kW	0.75
Total cost of installation	USD	1,750

Table 3.41. Economic indexes of installation for drying medicinal plants

Indicators	Units	Value
Productivity	t/season	2.0
Raw material consumption	t/season	8.5
Raw material price	USD/t	50
Electrical energy consumption	KWh	282
Total annual cost	USD	594
Selling price of production	USD /kg	0.5
Net annual value	USD	400
Raw material price	USD	3,460

3.2.4.3. Cost analysis of pumping installations for small irrigation

1. Possible variants of electricity supply for pumping installations

For potential consumers of PV electrical energy – FE that need water for irrigation – there are possible the following variants of feeding with energy of the pumping installations:

a) Connection of pumping installations at the public electrical network;
b) Utilization of motor-generator set;
c) Utilization of autonomous PV systems for electrical energy production.

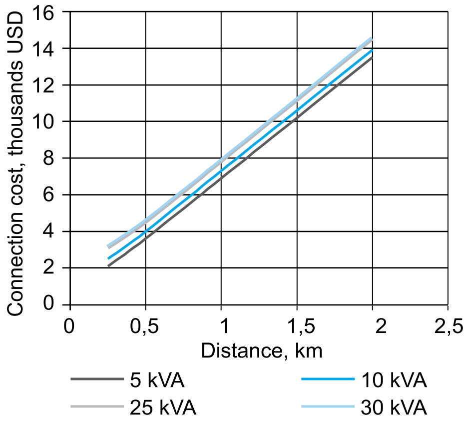


Figure 3.33. Connection cost to public network depending on the electrical line length and transformer's capacity

2. Wiring connection cost

On the basis data of supplied by the Institute "Energoproiect", there have been calculated connection cost depending on the electrical lines length and the transformer's capacity. The results are presented in figure 3.33. We state that the transformer's capacity does not influence significantly the costs. The difference do not exceed 20 % for a length of 0.5 km, 14 % - for 1 km and 8 % for 2 km. Therefore, we will operate with the average cost of wiring connection only depending on the line length (*table 3.42*).

Table 3.42. Average costs of connection at the line length, km

Length, km	0.25	0.5	1.0	1.5	2.0
Average cost, thousands USD	2.5	4.2	7.5	10.9	14.1

3. Cost of a cubic metre or water

As an economic indicator for all variants, it was accepted the cost of a m³ of water for total manometrical heights (T.M.H.) of 10-60 m, debits which varies between 10-100 m³/day. This water volume affords the agricultural land irrigation with surfaces comprised between 0.5 and 5 ha, in case of sprinkler irrigation and some surfaces twice bigger in case of drop irrigation. As follows, we will determine the cost of a m³ of water for possible feeding energy variants, mentioned above.

a) Case of connection to the public electrical network

Initial data:

- Investment cost of connection is determined from table 3.50;
- Annual expenses for personnel remuneration, the maintenance and the equipment repairs are considered at the level of 6 % of the total initial investment [44];

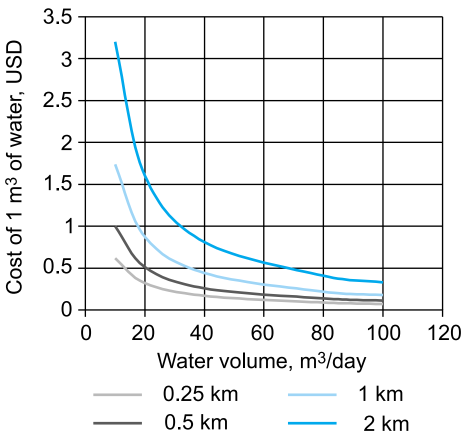


Figure 3.34. Cost variation of m³ of water depending on the daily consumption and the length of electrical line

- Energy losses in the electrical line and transformer constitutes 5 % of the consumed energy;
- Study period T = 20 years;
- There are utilized electrical pumps with dry rotor, their operating period being of 9,000 h [45]; for the research period there is performed the pump renovation over 10 years;
- Operating period by season is 900 h;
- Discounting rate i = 10 %;
- Inflation rate r_I = 3 % (reporting to USD).

We state an essential dependence of the cost one cubic water metre on the line length and on the pumped water volume by day. T.M.H. influence slightly the cost and doesn't exceed 5 % for T.M.H. limits from 10 to 60 m. This is explained by relatively small expenses regarding electrical energy cost.

Table 3.43. Cost of one m³ of water. Case of connection at the public network

Water volume, m³/day	Cost of one m³ of water			
	Electrical line length			
	0,25	0,5	1,0	2,0
10	0,62	1,0	1,74	3,2
20	0,32	0,51	0,87	1,6
40	0,17	0,26	0,44	0,81
80	0,09	0,14	0,22	0,41
100	0,07	0,11	0,18	0,33

b) Case of using an electric set

The indexes for the related calculation includes:
1) Investments:

- The cost of an electrogen unit;
- Cost of renovating the gasoline or Diesel oil engine and the pump. Engine's repowering is performed over 7 and respectively 14 years and the pumps one over 10 years. The operating period of the generator is equal to the study period of 20 years;

2) Operation and maintenance cost (personnel, current repairs, oil, etc.) constitutes 9 % of the electric set cost and of the electrical pump [46].
3) Fuel cost: gasline – 0.45 USD/l, Diesel oil – 0.35 USD/l. it is considered also the inflation rate.

The results are included in table 3.44 and in figure 3.35.

Table 3.44. Cost of one m³ of water. Electrogen unit case

T.M.H w.c.m.	Cost of one m³ of water				
	Water volume, m³				
	10	20	40	80	100
10	0.40	0.24	0.16	0.15	0.13
20	0.54	0.35	0.30	0.24	0.23
40	0.82	0.67	0.48	0.46	0.37
60	1.30	0.92	0.69	0.66	0.61

c) Case of using a PV system

The indexes for the related calculation includes:

- ❑ The PV modulus cost is taken in conformity with [29]. In 1999 the cost of a watt was of 3.3 Euro. By extrapolating the price for the 1997-1999 period, in 2002 there was obtained a price of 2.85 Euro/W_c or 2.75 USD/W_c, which includes also the transportation expenses.
- ❑ The price of the PV system's components is settled depending on the initial investment and according to [47], constitutes:
  - PV modulus - 81.9 %;
  - The base structure, foundation, lay – 3.8 %;
  - Converter c.c./c..a. - 12.4 %;
  - Other costs – 1.9 %.
- ❑ The converter's lifetime period is 10 years. During the study period there is performed its renovation.
- ❑ It is considered that the annual operation and maintenance cost constitutes 1 % of the total initial investments [46].

The calculation results are included in table 3.45 and in figure 3.36. Unlike the connection to the public network, in the second and the third cases there is stated a considerable variation of a m^3 of water cost depending on T.M.H., which is explained by the growth of electrogen unit capacity, respectively of PV modulus and as a consequence of initial investments.

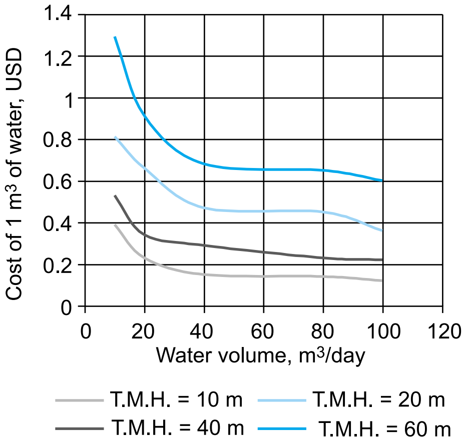


Figure 3.35. Cost of one m^3 of water depending on the daily consumption and on T.M.H. Case of using an electrogen unit

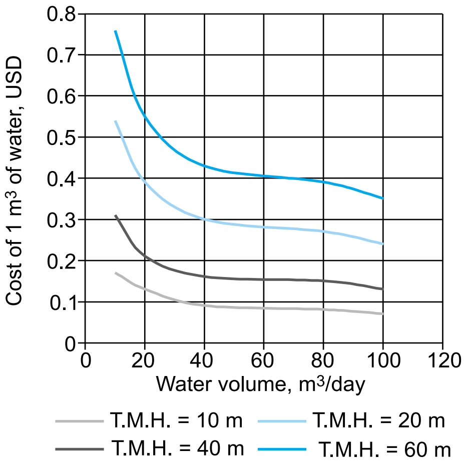


Figure 3.36. Cost variation one m^3 of water depending on the daily consumption and on T.M.H. Case of using a PV system

Table 3.45. Cost one m^3 of water. Case of using a PV modulus

T.M.H w.c.m.	Cost of one m³ of water				
	Water volume, m³				
	10	20	40	80	100
10	0.17	0.13	0.09	0.08	0.07
20	0.31	0.21	0.16	0.15	0.13
40	0.54	0.39	0.30	0.27	0.24
60	0.76	0.55	0.43	0.39	0.35

4. Variants comparison from the economic point of view

In figures 3.37-3.40 there are presented the costs of one m^3 of water for different T.M.H. and those three variants of the pumps electricity supply: by connection, by using the electrogen unit or a PV system. With a view to this, we conclude:

a) For T.M.H. comprised between 10-60 m and with a daily consumption of 10-100 m^3 of water, the use of photovoltaic solar energy is more advantageous as comparing to an electrogen unit. The cost of one m^3 of water is lower in the case of PV system use by 1,6-2,4 times. As smaller T.M.H. is, so greater are the cost difference.

b) Comparing to the wire connection, the PV system advantage depends on three factors - T.M.H., the electrical network line length and the daily consumption. Thus, we state the following:

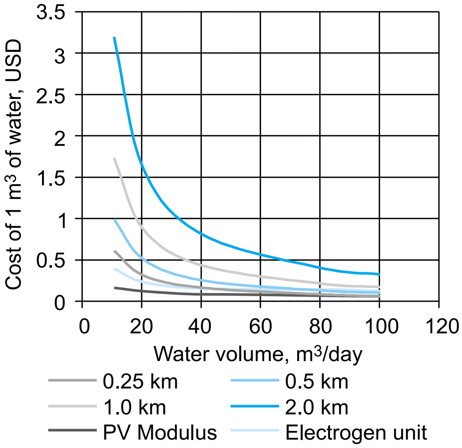


Figure 3.37. Cost one m^3 of water T.M.H.=10 m

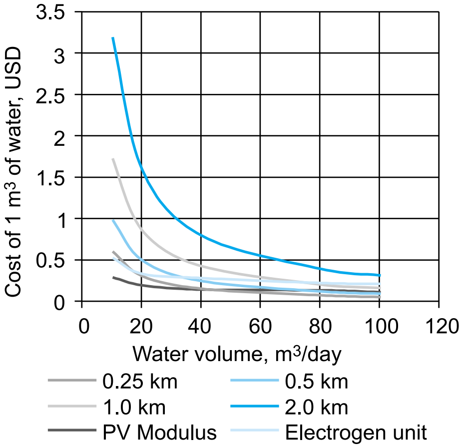


Figure 3.38. Cost one m^3 of water T.M.H.=20 m

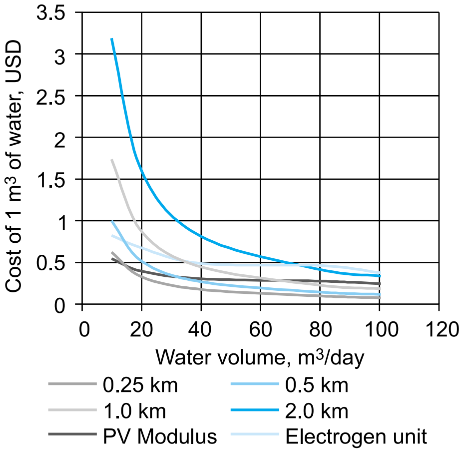


Figure 3.39. Cost one m^3 of water T.M.H.=40 m

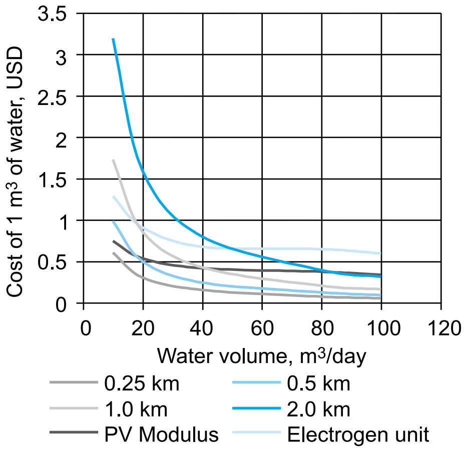


Figure 3.40. Cost one m^3 of water T.M.H.=60 m

- For T.M.H.=10 m the cost of one water m^3 is smaller in case of solar energy use and the variants become equivalent if the consumption exceeds 100 m^3/day (*figure 3.37*);
- For T.M.H.> 20 mm, the cost of one water m^3 depends on the daily consumption and in case of solar energy use is smaller, if:
  - T.M.H.= 20 m, the electrical network line length is smaller than 0.25 km and the daily consumption does not exceed 40 m^3;
  - T.M.H.= 40 m, the electrical network line length is smaller than 0.5 km and the daily consumption does not exceed 30 m^3;
  - T.M.H.= 40 m, the electrical network line length is smaller than 1.0km and the daily consumption does not exceed 65 m^3;
  - T.M.H.= 20 m, the electrical network line length is smaller than 0.5 km and the daily consumption does not exceed 20 m^3;
  - T.M.H.= 60 m, the electrical network line length is smaller than 1.0 km and the daily consumption does not exceed 40 m^3;
  - T.M.H.= 60 m, the electrical network line length is smaller than 2.0 km and the daily consumption does not exceed 80 m^3;

c) The PV system is not efficient if T.M.H.> 60 m and the electrical network line length does not exceed 0.25 m.

3.2.4.4. Economic indexes of PV installation for an antihail station electricity supply

In table 3.46 are presented characteristics of two options of antihail station electricity supply: the existent one – only from accumulators and the modernized one – from accumulators and PV modulus.

For an antihail station it was calculated per season the cost of one kWh of electricity for both supply options. The calculations were performed in the following terms (*table 3.47*):

Table 3.46. Characteristics of electrical energy feeding variants of an antihail station

Components	Variants			
	Accumulators		Accumulators plus PV modulus	
	Characteristics	Cost, USD	Characteristics	Cost, USD
Operating accumulators	8 batteries, capacity 8x80 Ah	800	3 batteries, capacity 3x28 Ah	420
Back-up accumulators	2 batteries, capacity 2x80 Ah	200	-	-
PV modulus	-	-	One PV modulus, 50 W_c	138
Support, wiring	-	-	1	8
Converter c.c./c.a./c.c.	-	-	2 W	2
Control assembly	-	-	1	80
Liquified fuel for transport	105 l/season	180*	30 l/season	52*
Electrical energy for recharge	56 kWh/season	11*	-	-

* Discounted cost considering the inflation rate

Table 3.47. Cost analysis for a season period of the electrical energy feeding variants of an antihail station

Index	Feeding variants with electrical energy	
	Accumulators	Accumulators plus PV modulus
Total investments, USD	2,000	1,108
Substituted liquid fuel, l	-	75
Substituted electrical energy, kWh	-	56
Total substituted energy, kWh	-	696
Cost of one kWh of electrical energy, USD/kWh	82	15

- The stations operating period: April – September;
- The study period: T = 20 years;
- Accumulators time of operation: 7 years:
- PV modulus time of operation: 20 years;
- Electronic components operating time: 10 years;
- Antihail station's energy consumption per season;
- Accumulators variant: 7.4 kWh;
- Accumulators plus PV modulus variant: 18.7 kWh.

- Discounting rate 10 %, inflation rate 3 %;
- Average distance between the accumulator's recharge center and the antihail station: 50 km;
- Fuel cost: 0.45 USD/l;
- Operation and maintenance cost for both variants: 9 %.

3.2.5. Environmental benefits assessment as a result of solar energy implementation

3.2.5.1. General aspects

The RES utilization affords the diversification of energy feeding sources and the substitution of fossil fuels, imported by the RM. Besides that, RES are pure energies from the ecological point of view and contributes to the reduction of greenhouse gas (GHG) emissions.

In order to estimate the contribution of one m^2 of solar conversion collector for water heating or for drying agricultural produce or of one m^2 of PV modulus for water pumping, there has been calculated:

- Thermal or electrical energy produced by the installation during an operating year;
- The quantity of substituted fuel;
- The quantity of reduced GHG emissions that correspond to a m^2 of conversional solar collector or to a PV modulus.

For this reason, there were used data regarding efficiency, for the operating period of the solar installations and of those on fossil fuel (*table 3.48*), referring to the GHG emissions calculated for types of fuels used in RM (*table 3.49*), and regarding the solar energy potential on the RM's territory for the related periods (paragraph 3.2.2).

Table 3.48. Average efficiency of solar installations and of installations on fossil fuels

Energy conversion installation	Efficiency, %
Solar collector for water heating, during the period 15 March – 15 October	40
Solar collector for drying agricultural products; operating period: May – October	45
PV modulus for water pumping; operating period: April – September	14
Boiler for water heating on natural gas	80
Boiler for water heating on heavy oil (Diesel oil)	75
Boiler for water heating on coal	65
Diesel Motor, 1-5 kW	25 - 35
Heating plate on liquid gas	60
Electrical boiler	90
Electrogen unit, 1-5 kW_E	17 - 28
Electrical energy production	35

The calculation results are included in table 3.50. It should be stated that from the point of view of thermal energy substitution all those three conversion technologies of the solar energy are almost identical (one electrical energy kWh produced by a PV modulus is equivalent approximately to three kWh of thermal energy used at a power plant). As well, all technologies are equivalent in the meaning of GHG emissions reduction. The effect is greater by 20 % (table 3.50) in the case of photovoltaic energy use for the Diesel oil or liquified gas substitution, fuels necessary for electrogen units that are feeding the pumping installations with electrical energy.

As follows we ll assess the environmental effects that can be obtained as a result of implementing the solar energy technologies in the proprietary fields.

Table 3.49. GHG specific emissions as a result of electrical energy production and combustion of used fuels in the RM

Fuels	GHG specific emissions	
	kg/GJ	kg/kWh
Electrical energy	70	0.252
Natural gas	59	0.212
Liquified gas	64	0.230
Diesel oil	75	0.270
Heavy oil	78	0.281
Gasoline	71	0.256
Coal	100	0.360

3.2.5.2. Assessment of fossil fuels substitution potential and reduction of greenhouse gas emissions

1. Water heating in the residential sector of the rural settlements

In paragraph 3.2.3 it has been stated that the greatest weight of the thermal energy demand for water heating in the rural settlements of the RM correspond to the residential sector, this constituting 85.6 %. Suppose that the substitution

Table 3.50. Contribution of one m² of solar collector for water heating (or for drying agricultural produce, or of an m² of PV modulus for water pumping) at the reduction of fuel expenses and GHG emissions

Characteristics	Solar collector for: Water heating	Solar collector for: Drying agricultural products	PV modulus for water pumping
Thermal or electrical produced energy, kWh	437	423	112
Natural gas substitution, m³/year Reduction of GHG emissions, kg/year	55 116	53 112	- -
Liquified gas substitution, kg/year Reduction of GHG emissions, kg/year	- -	- -	59 152
Diesel oil substitution, kg/year Reduction of GHG emissions, kg/year	47 147	46 143	57 178
Coal substitution, kg/year Reduction of GHG emissions, kg/year	83 242	80 234	- -
Electrical energy substitution, MWh/year Reduction of GHG emissions, kg/year	485 315	470 305	112 81

rate of the thermal energy demand for water heating by the solar energy is 50 %. Considering the structure of the fuel consumption in the rural sector, we acknowledge the following quota of fuel used for water heating: 15 % - natural gas; 30 % - liquified gas; 25 % - coal; 5 % - diesel oil; 5 % - electrical energy; 20 % - woods and woods' wastes. Because woods do not determine the majority of GHG emissions, these were not counted. On the basis of specific thermal energy demand (paragraph 3.2.3.2), on data regarding the previous paragraph (installations' efficiency, GHG specific emissions) and on the fuels' thermal power [48], there have been calculated (*table 3.51*):

- The quantities of fossil fuels substituted by solar energy in natural units of conventional fuel;
- GHG emissions reduction.

2. Installations for drying fruits, vegetables and medicinal plants

In paragraph 3.2.3.4 there has been assessed the thermal energy which constitutes 9.34×10^3 GJ. We acknowledge the following usage quota at present of fossil energy resources in order to meet this demand: petrol or residual fuel oil– 60 %; natural gas – 35 %; electrical energy – 5 %. The solar energy use will lead to the substitution of fossil sources and to the reduction of GHG emissions in quantities specified in table 3.52.

Table 3.51. Quantities of substituted fossil fuel and the GHG reductions as a result of implementing solar installations for water heating in the dwelling sector

Fuel	Thermal energy demand GJ·10³	Fuel substitution: Natural units	Fuel substitution: t.c.e.·10³	GHG reductions, thousands t
Natural gas	503	15.10^6 m³	18.3	29.7
Liquified gas	1,338	$26.8 \cdot 10^3$ t	44.8	85.6
Coal	1,029	$46.8 \cdot 10^3$ t	36.4	102.9
Residual fuel oil	179	$4.4 \cdot 10^3$ t	6.3	14.0
Electrical energy	425	$425 \cdot 10^3$ GJ	14.6	10.4
Total	3,474	-	120.4	242.6

Table 3.52. Quantities of substituted fossil fuel and GHG emissions reductions as a result of implementing solar installations for drying fruits, vegetables and medicinal plants

Fuel	Thermal energy demand GJ·10^3	Fuel substitution		GHG reductions, thousands t
		Natural units	t.c.e.	
Natural gas	3.27	99.1·10^3 m^3	120.9	193
Residual fuel oil (Diesel oil)	5.6	136.6 t	195	420
Electrical energy	0.48	1.37·10^3 GJ	47.2	33.6
Total	9.35		363.1	646.6

3. Pumping installation for the small irrigation

The substitution of electrical energy demand of 3.2x10^3 MWh for the small irrigation (see paragraph 3.2.3.5) by the photovoltaic electrical energy, will allow the reduction of fossil sources and GHG emissions reductions in quantities specified in table 3.53. The comparison calculations were performed for pumping installations fed by an electrical network or by an electrogen unit on Diesel oil.

4. Installations for electrical energy feeding of the antihail stations

At an antihail station it is substituted the liquid fuel (gasoline or Diesel oil) necessary for accumulator's transportation and electrical energy that will be consumed for their recharge. Supplementary, there is reducing the quantity of nocive wastes by 5.6 t that are formed annually as a result of accumulator's renovation. Calculations were performed for 150 existing antihail units. The season period comprise April – September months. The results are indicated in table 3.54.

Solar energy implementation in the paramount fields mentioned in paragraph 3.2.1.4 will allow the annual substitution of 122,521 t.c.e. of fossil fuel, which constitutes about 5.5 % of the used fuel resources in 2000. The reduction of GHG emissions will constitute 247,027 t.

Table 3.53. Quantities of substituted fossil fuel and the GHG emissions reductions as a result of implementing PV installations for water pumping

Variants o electrical energy feeding	Electrical energy demand	Energy or fuel substitution		GHG emissions reductions, thousands t
		Natural units	t.c.e.	
Public network	11.52	3.37.10^3 MWh	1,180	2,427
Electrogen unit	11.52	1,220 t	1,742	3,750

Table 3.54. Quantities of substituted fossil fuel and the GHG emissions reductions as a result of implementing PV installations for electrical energy feeding of the antihail stations

Energi or fuel	Energy or fuel substitution		GHG emissions reductions, thous. t
	Natural units	t.c.e.	
Electrical energy	8,400 kWh	3.0	2.0
Diesel oil	9.0 t	13.0	28.0
Total	–	16.0	30.0

3.3. Feasibility study regarding biomass energy use in Republic of Moldova

3.3.1. Methane emissions: sources of atmosphere pollution

Among the greenhouse gases (GHG), there can be identified: water vapors, carbon dioxide (CO_2), methane (CH_4), nitrogen oxide (N_2O), ozone (O_3), chlorofluorocabons (CFC), hidrochlorofluorocarbons (HCFC) and others. A national greenhouse gas inventory was presented in “First National Communication of the Republic of Moldova, under the United Nations Convention on the Climate Change” [51].

The current research is dedicated to methane emissions, their main sources indicated in the mentioned inventory, being:

a) In the energy sector:
- Fugitive emissions of the transport and the natural gas distribution (leaking);
- Losses which result from natural gas firing in the means of transport, kettles etc.

b) In agriculture:
- Enteric fermentation;
- Manure management;
- Agricultural residues burning.

c) In waste management:
- Solid organic wastes disposal on land;
- Industrial wastewater handling and treatment of sludge proceeded from it;
- Domestic wastewater handling, treatment of sludge proceeded from used water treatment station, of settlements endowed with sewerage.

On the basis of the First National Communication data [51], there follows a short analysis on CH_4 emissions, of which results the necessity of recovering the related gas.

The dynamics of CH_4 emissions between 1990-1998 is presented in table 3.55, including the main sources: energy, agriculture and the wastes. Thus, it is being proved an important reduction of those, as a result of the economic crisis, the weight of the related gases constituting about 24 % in 1994 and 44 % in 1998 towards the registered emissions in 1990.

The CH_4 emissions’ distribution, expressed in CO_2 equivalent, for the period 1990-1998 reported to CO_2 emissions and to the total of greenhouse gases, as well expressed in CO_2 equivalent, is presented in table 3.56. The data demonstrate an increase of CH_4 emissions share as reported to CO_2 from 14 to 29 % and as reported to the total of GHG – from 12 to 22 %. Thus, there takes place a significant increase of CH_4 emissions weighted to the total GHG emissions. But it does not permit us to neglect them, also considering the report equivalent in CO_2 of CH_4 emissions, expressed in mass units - 21 (meaning 1 Gg of CH_4 is equivalent to 21 Gg of CO_2).

Table 3.55. Dynamics of CH_4 emissions (Gg) of the main sources for the period of 1990-1998

Years	Total	Including					
		Energy	Agricul-ture	Wastes			
				Total	Including		
					Solid Waste Disposal on Land	Industrial Wastewater Handling	Domestic Wastewater Handling
1990	193.27	54.05	101.21	36.57	34.60	0.78	1.19
1991	183.76	46.36	99.66	36.50	34.68	0.63	1.19
1992	164.19	40.64	97.51	24.73	23.01	0.54	1.18
1993	144.37	25.65	93.27	24.45	22.86	0.41	1.18
1994	146.83	32.46	89.22	24.35	22.93	0.25	1.17
1995	134.26	26.58	82.70	24.18	22.79	0.22	1.17
1996	128.19	29.54	73.91	23.84	22.47	0.21	1.16
1997	117.91	29.51	63.87	23.74	22.37	0.20	1.17
1998	107.43	25.29	57.08	23.63	22.28	0.20	1.15

Table 3.56. Dynamics of CH_4 emissions expressed in CO_2 equivalent (Gg) of their proportions towards CO_2 and the total of GHG, for the period of 1990-1998

Sources	Years								
	1990	1991	1992	1993	1994	1995	1996	1997	1998
Energy sector	1,135.15	973.46	853.47	538.68	681.73	558.23	622.44	619.63	530.99
Agriculture	2,125.4	2,092.82	2,047.67	1,958.69	1,873.67	1,736.60	1,552.16	1,344.24	1,300.68
Wastes	768.22	766.58	519.39	512.42	508.64	507.26	500.61	497.95	497.83
Total CH_4 emissions	4,058.74 (193.27)	3,859.03 (183.76)	3,447.97 (164	3,030.70 (144.37)	3,080.78 (146.83)	2,818.83 (134.26)	2,691.41 (128.19)	2,475.56 (117.91)	2,359.67 (107.43)
Total CO_2 emissions	28,323.96	25,485.54	19,494.82	14,455.37	12,085.79	9,449.27	9,984.14	9,016.44	8,129.31
Total GHG emissions	33,272.57	30,141.62	23,538.68	17,777.10	15,358.77	12,455.06	12,861.18	11,604.91	10,620.59
% of CH_4 emissions in report with CO_2	14.33	15.14	17.69	20.97	25.49	29.83	26.96	27.46	29.03
% of CH_4 emissions in report with the total of GHG	12.20	12.80	14.65	17.05	20.06	22.63	20.93	21.33	22.22

Considering also the data of figure 3.41, we conclude that of those three gases with greenhouse effect (CO_2, CH_4 and N_2O), the methane weight is the most significant as if it is to consider the attenuation of emissions: and as polluting potential of the atmospheric air and as possibilities of total emissions reduction, by recovering this gas, that mainly proceeds from the zoo-technical sector and as a result of poor management of wastes.

Analyzing the volumes and the sources of methane emissions, as well as the possibilities of the existent technologies, the present research focuses on the recovery and utilization of the resulted methane of the solid wastes' decomposition, animal dejections, residual and used wastes, as well as on the treatment plants sludge, all of them being of organic origin and carrying the generic nomination of biomass.

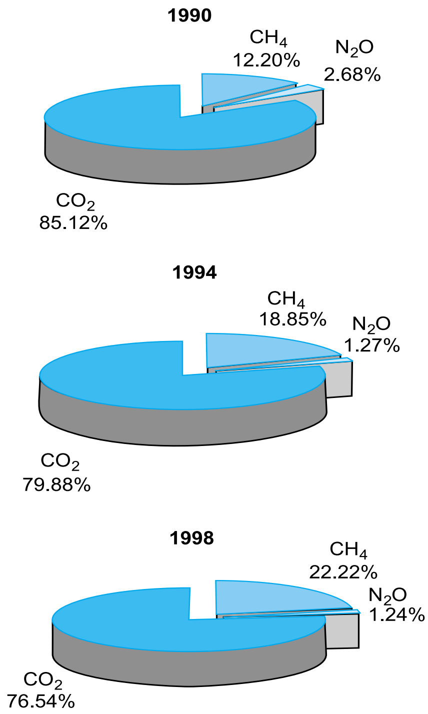
The attenuation of methane emissions using these procedures has a double effect:

1) avoidance of atmospheric air pollution and reduction of the greenhouse effect, which lead to the planet climate change and
2) substitution of polluting fuels by the biomass renewable energy used in energetics;

As collateral effect of anaerobic fermentation technologies of biomass, there can be outlined the following:

3) exclusion of occupancy of large territories by wastes and sludge storage on a long term;
4) biomass reintegration in the natural circuit as organic fertilizers and other modalities (figure 3.42);
5) country's contribution for durable development, having the advantage of employing a part of the population;
6) ecological and aesthetic education of the population by implementing technologies and recycling organic wastes.

Figure 3.41. The structure of total greenhouse direct gas emissions expressed in CO_2 equivalent in 1990, 1994 and 1998



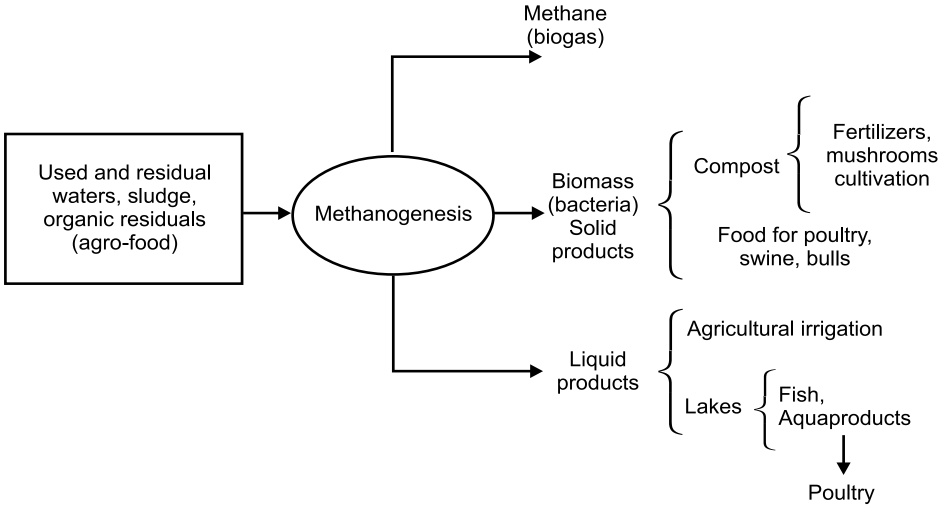


Figure 3.42. Ecological and economic integration of anaerobic fermentation of organic residuals (methanization)

3.3.2. Assessment of biomass energy potential

***Biomass is the vegetal planet coverage that counts over 1,800 billion t, of dry substanc*e**. Woods constitute about 68 % of the terrestrial biomass, the herbal ecosystems - about 16 %, and the harvested lands – 8 %. Over the hole planet, by photosynthesis there are produced 173 billion t of dry substance yearly, quantity that is 20 times greater than the entire volume of fossil energy, consumed annually in the world. This considerable biomass potential being exploited, constitutes the 7th part of the world consumed energy – the equivalent of over 3 billion t of petrol by day.

The main biomass generators, used in energy goals in the RM are silviculture, agriculture, zoo technique sector, food industry and communal enterprise of the residential sector [55]. In figure 3.43 there is presented the potential and the quantitative distribution of the biomass proceeded from the agricultural sector, as one of the most important sectors of the RM.

In this study, the term of biomass is treated moreover as the different residuals and organic origin wastes, than the organic mass proceeded from the growing process of the agricultural plants and of silviculture.

These wastes have an incontestable contribution to the climate change, because as a result of the microbe activity, they are subjected to a degradation in natural anaerobic conditions with different gas emissions and first of all – of methane. As it was mentioned before, the strict mean of the “biomass” term refers to any organic material, derived from the active photosynthetic cycle.

As it was already proved that residuals and wastes are a form of renewable biomass, it would be rational to know the indicated methods of effective use of this material. It is known that the organic substance, the nutritive substances (M, P, K) and the microelements contained in residuals, wastes, sludge, dejections, etc. are useful for the soil. Their incorporation in the fields and the compost represent obvious advantages for soil’s fertilization. The organic substance can be assessed as a renewable energy source. For example, as a result of anaerobic fermentation of 360 m^3 of sludge, accumulated at the treatment plant of mun. Chisinau, from a fermentation cabinet with a volume of 3,600 m^3 there can be obtained daily 6,000 m^3 of biomass, volume equivalent to 3,200 l of diesel oil. The related quantity is a significant source of renewable energy and the recovery of this energy potential can not be neglected because it presents a judicious option of using the sludge.

The fossil / traditional fuel combustion (coal, oil, natural gases) lead to the issue in the atmosphere of that CO_2, which was eliminated long time ago by photosynthesis. At a strong CO_2 emission, resulted of fossil fuels, the atmosphere can not be counterbalanced that has as a consequence a net increase of the CO_2 concentration and respectively, of the greenhouse effect. As a result, fossil fuels will have to be substituted by RES, particularly by solar and wind energy, by biomass (including, wooden substance ad other vegetation). So long as wastes, residuals of the biogas are used usefully for obtaining energy, there is avoided the consumption of an equivalent value of fossil fuels. Thus, as a result of the biogas recovery of wastes there is obtained a benefic effect for the environment.

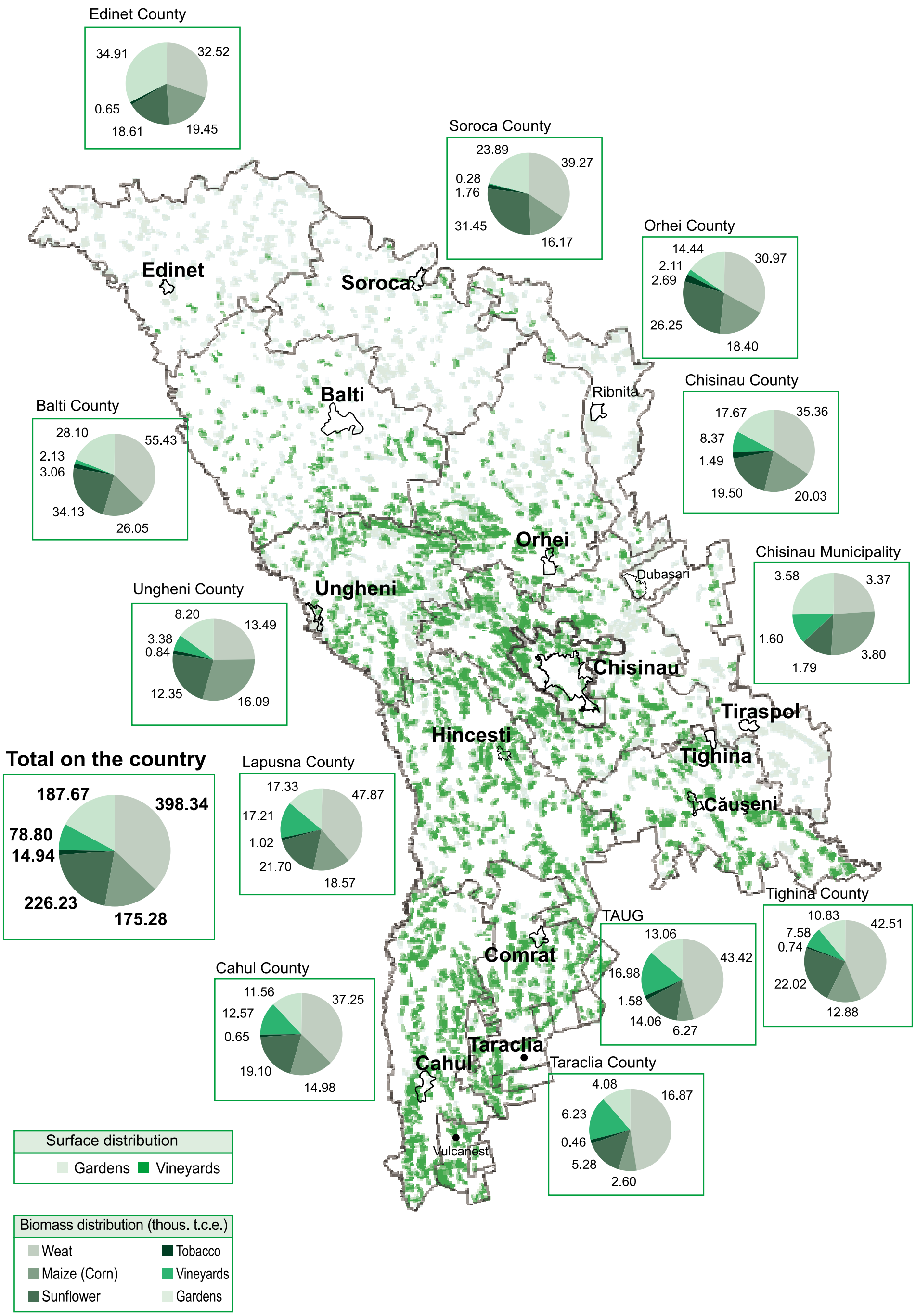


Figure 3.43. Quantitative distribution of agricultural biomass, 2001 year

The general methane weight in the process of planet warming is determinant, because this gas is more effective by 24.5 times (± 35 %) at the settlement of the heat in the atmosphere for the prospect of the next 100 years [60].

From this reason, the option of reducing methane emissions offer one of the most efficient solutions for planet warming attenuation on short term.

So, the directly issued in the atmosphere methane is a gas with a major greenhouse effect, but being recovered / collected and used, with the transformation into water vapors and carbon dioxide becomes a renewable energy source.

3.3.2.1. Classification of organic residuals appropriate to anaerobic degradation

Wastes and organic residuals resulted of animal growing process, of food industry, utility enterprise, represent huge environment polluting biomass quantities.

Fortunately, by using biotechnologies the biomass can be used for obtaining biogas or alcohol, which at their turn can replace partially the fossil hydrocarbons, as well as for producing a large range of useful substances for food industry, pharmaceutics, chemical industry etc.

Speaking of dry substances, the simplest and the most used way at present – of transforming the biomass into energy – is the firing, which supplies heat, transformed at it turn into metrical force or electricity.

For wet materials and liquid residuals, the oldest and at the same time the most efficient channel represents the biogas conversion with a prevalent content of methane.

The main sectors and producing areas of organic materials in the shape of residuals are the agriculture, food industry, zoo technical sector, used waters treatment plants, municipal services and industrial enterprises.

3.3.2.2. Agricultural residuals

According to a calculation performed in USA [62], in 45.4 kg of wastes – daily quantity that corresponds in an average per capita – the organic material represents 34 kg, which include a quantity of 2.3 solid domestic wastes, 0.1 kg sludge of the treatment plants and almost 30 kg residuals of the animal growth and secondary products of agriculture.

The organic material reported to the dry substance represents between 92 and 98 % in the secondary products of agriculture, between 80 and 85 % in animal dejections, 73 % in poultry dejections, around 90 % in manure, between 32 and 56 % in garbage (solid domestic wastes).

A comparative assessment of some organic materials capacity of biogas producing can be performed analyzing the bellow tables.

Of the presented data in table 3.57 results that the decomposition degree of the solid substances is greater at secondary vegetal products as comparing to the

Table 3.57. Decomposition degree for different natural organic materials by anaerobic fermentation, for a period of 30-40 days [62]

Organic material	Quantity of discomposed dry substance	CH_4 content % of produced biogas)
Chaff	68 – 83	62
Sunflower stems	61	-
Corn teams	58	53
Corn cobs	35 - 57	53
Flax straws	48	59
Wheat straws	46 - 49	58
Potato creping stalks	41	60
Deciduous leaves	34 - 40	59
Dejections of bulls	35	60
Manure	20	60
Pea creping stalks	12	60

Table 3.58. Quantities of recoverable biogas of different organic materials [62]

Source	Organic material character	Biogas (l / kg d.s.)	Methane content, (%)
Agriculture	Different herbs	557	84.5
	Alfalfa	445	77.7
	Tree leaves	260	58
	Entire wheat straws	367	78.5
	Idem, sliced at 0.2 cm	423	81.3
	Barley straws	380	-
	Rice straws	360	-
Agro-food industry	Sugar beet leaves	501	84.8
	Fodder beet leaves	496	84
	Tomatoes tendrils, sliced	606	74.7
	Flax or hemp steams	369	-
	Dregs of distilleries	300 - 600	58
Animal breeding sector	Poultry manure	520	-
	Swine manure	480	60
	Bovine manure	260 - 280	50 – 60
	Ovine manure	320	65
	Horse manure	200 - 300	-
Population service enterprises	Human faeces	240	50
Treatment plants	Sludge	370	60 – 65

dejections of a bull and the manure, which proves, that the first ones shouldn't be neglected.

The biogas quantities that could be obtained from different organic materials are presented in table 3.58.

Data of table 3.59 represent the quantity of recoverable biogas by anaerobic fermentation of animal dejections in systems of high efficiency. It's also stated that the bovine dejections have the lowest decomposition degree of the organic material – 35 % and those of poultry the highest – 60 %. The anaerobic

Table 3.59. Typical values for assessing biogas-generating potential of animal dejections in anaerobic fermentation systems of high efficiency, of medium capacity [62]

Specification	Dairy cattle	Fattened for slaughter taurines	Fattened for slaughter swines	Biddies
Undiluted fresh faeces together with urine* (l / 1,000 kg animal · day)	82	60	65	53
Total quantity of dry substance (kg d.s. / 1,000 kg animal · day)	10.6	7.4	5.9	12.9
Quantity of organic material (kg o.m. / 1,000 kg animal · day)	8.6	5.9	48	9.5
Fraction of organic material converted in biogas (%)	35	45	50	60
Quantity of produced biogas **:				
1. m^3 / 1,000 kg animal · day	3.28	2.89	2.62	6.21
2. m^3 / l of undiluted dejections · day	0.04	0.048	0.04	0.117
3. m^3 / kg o.m.	0.38	0.49	0.54	0.65
4. m^3 / m^3 fermentator · day	1.1	1.3	1.1	1.3

*) *In order to assess the volume of undiluted faeces plus the urine, there is multiplied the member of animals by their average weight, then it's divided by 1000 and multiplied by the number of the table.* Example: 200 hens · 2.5 kg · 1 / 1000 kg · 53 l /day = 265 l.

**) *Assessed quantity, considering that there is produced 1.09 m^3 biogas (65 % CH_4, 35 % CO_2) by kg of decomposed organic material.* Example: in the case of milk cows, biogas generating potential is of 35 · 8.6 : 100 · 1.09 = 3.28 m^3 / day / 1,000 kg animal.

fermentation of the animal dejections is widely spread in Western Europe (*table 3.60*).

For instance, about 150 of installations are relatively new (built offer 1998), of which about 120 only in Germany. Most of them are of low and medium capacity, permitting to treat from 1 to 20 m^3 / day organic material. Nine installations in Germany treats over 20 m^3 / day organic material [63].

The existent installations in Europe can be classified as:

Table 3.60. Biogas installations for animal dejections treatment existent in Europe [63]

Country	Number of installations
Germany	200
Switzerland	90
Austria	50
Great Britain	30
Denmark	28
Italy	20
France	15
Sweden	5
Other countries	30
Total	***470***

- of low and medium capacity, individual;
- of large capacity, individual (using advanced technologies, industrially built);
- common joint (collective), by collecting dejections of individual farmers and industrially built, using advanced fermentation technologies.

Low capacity installations represents about 70 % of the existent installations, being used of about 60 years. In Switzerland, Austria, France and Great Britain prevail small, individual installations. Half of those 28 ones installations in Denmark, are of low and medium capacity. About 190 of the existent installations in Germany are of the same category, 25 of these being built in the last 10 years.

There can be mentioned two types of fermenting tanks used in the treatment plants of animal dejections:

- horizontal of steel, equipment with standard reservoirs of steel foreseen for liquid fuel keep;
- vertical of steel, endowed with type-reservoirs for keeping different liquids.

The horizontal metallic fermenters have volumes of 50 to 100 m^3, more seldom of 150 m^3 and are endowed with horizontal shaft pug mill equipment.

For plants of medium capacity there are used, usually, vertical reservoirs (cylindrical) of steel concrete, which volumes vary between 250 and 600 m^3, but also frequent are those from 800 to 1,200 m^3, having depths between 3 and 6 m and the diameters between 8 and 16 m. Often, these are built under ground, thus ensuring both a space saving, and the thermal isolation. Till 1985 the majority of individual plants have been using the biogas only for heating.

At present, most installations are based on cogeneration technologies producing electricity, with recovery the heat as a secondary product, for heating the dwellings or the water. The biogas is stocked in gas tanks with a capacity of 60-100 m^3.

The big majority of low, medium and individual installations are built with own possibilities. A fermentation plant of 100 cows dejection – type-plant, for example, for Germany costs 100,000 – 120,000 USD. The plant construction in Germany is subventioned in a volume of 20 – 25 %. In the same country the obtained electricity of biogas can be sold at a price of 0.1 USD / kWh. Thus, the cogenerated biogas brings an annual income of 2,000 USD from the heat recovery.

Biogas plants of high capacity are used for treating liquid dejections from the zoo technical complexes.

After 1990 in Germany there were built 5 such plants and several in the Netherlands, Great Britain and Denmark. On the ex-GDR (German Demogratic Republic) operate 7 plants with an efficiency of 20,000 m^3 / day biogas [63].

Collective (communal) plants of biogas are indicated for treating animal dejections collected from farmers. This kind of plants started to be operated about in 1985. At present, there operate 14 plants, which treat over 440 tons of animal dejections, accumulated from over 80 farms [63]. These plants are very solicited especially in Denmark, in the following reasons:

- the Danish tradition focuses on cooperating and concerning the community;
- the majority of dwellings are endowed with centralized heating system, that can use thermal energy recovered from biogas cogeneration systems.

This type of plants got a large spread due to the Danish energy agency implication, that initiated and supervised a special program for building centralized biogas installations. Animal dejections are collected by a special transport. Till the present, there has been used thermal mesophyll system (32 – 35 °C), in report of 10:5 toward the thermophilic fermentation system (50 –

55 °C). But lately 4 of 5 exploited installations, foresee the thermophilic fermentation system. A major problem of these plants derives performing the hygiene of (eliminating the pathogen micro flora) dejections. The biogas of the majority of installations is being cogenerated and the recovered heat is delivered in the municipal heating network.

At present, all the installations use as raw material not only animal manure, but also industrial organic residuals, especially those proceeded from food industry – till 37 % - that permitted to double or even to triple the biogas production and to stabilize the anaerobic fermentation process. One of the main problems of the personnel that is servicing these installations is the logistics and the dejection's transport. Organic residuals destined for fermentation in the related installations are collected on a radius of 10 km.

The operating parameters of the most representative communal / collective plants of Denmark, are presented in table 3.61.

In this country, the produced energy by 1 m^3 of biogas costs 0.28 USD, but when the gas is converted into heat and electricity, its cost rises to 0.42 USD. The collection and the dejection transportation imply 35-50 % of the total exploitation expenses. All the installations dispose of own vehicles, the external transport is used moreover for industrial residuals. In order to be economically balanced, first collective / communal installations needed substantial subsidiaries (30-40 %) and the new ones are subventioned in a volume of 20 %.

Let's describe an individual installation, typical for Germany. For instance, a farmer holds 70 cows and other 60 domestic animals and a biogas plant that operates from 1994, with the following characteristics (table 3.62).

The collective / communal installation of town Ribe, Denmark, the first biogas installation that operates in thermophilic regime (52-55 °C), was exploited in 1990, being the property of a joint stock company. The produced biogas is delivered to an CHP producing electricity and supplying the town with heat. Table 3.63 contains useful information on the operation of this intallation.

Table 3.61. Operating parameters of 10 collective plants of Denmark [63]

No.	Capacity m^3 / day	Animal manure, %	Organic residuals, %	Thermal regime of fermentation, °C	Fermentation duration, days	Biogas production, m^3 / day	Biogas utilization
1	44	63	37	37	34	4,400	Cogeneration
2	58	73	27	56	15	4,500	Idem
3	53	70	30	35	29	3,100	Idem
4	27	86	14	37	28	900	Heating
5	132	70	30	52	16	7,100	Cogeneration
6	152	77	23	37	21	7,100	Idem
7	37	75	25	44	15	1,200	Supplied in the network
8	402	84	16	53	12	11,800	Cogeneration
9	385	67	33	37	20	11,400	Idem
10	453	79	21	52	17	14,800	Idem

Table 3.62. Basic parameters of the individual biogas plant of Baden-Wurtenburg [63]

Indexes	Units
Daily feeding	6 m^3 / day
Fermentation volume	475 m^3
Thermal fermentation regime	37°C
Fermentator useful volume	425 m^3
Mixing equipment	Pale. 7.5 kW
Biogas production	150 m^3 /day (60% methan)
Necessary heat for maintaining the fermentation process	25% for fermentator heating
Biogas storage	Bottle of 70 m^3 placed into a container
Biogas use, cogeneration	Motor Diesel. 30 kW
Electricity production	90,000 kWh/year
Electrical energy consumption	20,000 kWh/year
Usage of recovered heat	50,000 kWh/year for heating the dwelling (220 m^2) and the water
Investment	150,000 Deutch Mark (DM)
Subvention	35,000 DM
Annual maintenance expenses	14,000 DM
Annual income obtained from electricity sale and oil economy	19,000 DM

Table 3.63. Basic indexes of the biogas collective plant of Ribe, Denmark [63]

Daily feeding with animal dejections	300 t/day
Daily addition of industrial residuals	40 t/day
Total volume of fermentation tank	4,650 m^3 (3x1,550 m^3)
Fermentation temperature	53°C
Biogas production	11,800 m^3/day (65% CH_4)
Heat consumption for maintaining thermal regime of fermentation	< 20%
Biogas storage	Tank of 1,000 m^3
Total investment	7.5 mil. $ US
Subventions	3.0 mil. $ US
Sales at 1 m^3 of raw material	8.20 $ US
Expenses at 1 m^3 of raw material	5.20 $ US
Net income at 1 m^3 of raw material	3.0 $ US

A) Proposals regarding the perform of biogas producing plants, of low capacity (husbandry system)

Generalities. Biogas is a gaseous product, resulted from anaerobic fermentation of the existent organic material in the animal and vegetal nature of individual, communal enterprises or small animal firms.

Of these raw materials (animal dejections, domestic wastes, human faeces, vegetal rests, etc.), after a fermentation duration of 30-60 days (variable depending on the content, temperature, humidity etc.) results:

- biogas with an inferior caloric power, of about 5,000 kcal / mc (methane content) – CH_4 – about 60 %;
- fermented sludge and water that can be used with good results as natural fertilizers.

Criterions regarding the establishment of plant's dimensions. The plant's measure is determined depending on the available raw material, on the capital for performing the investment and on the biogas necessary. The minimal fermentation volume corresponds usually to a liquid gas bottle is about 5 mc for a normal fermentation regime (heaten environment, with the characteristic temperature of 15 °C).

Practical case: a family of four persons holds a cow, a calf, two swine and twenty laying hens. Collecting all residuals of the husbandry, including vegetal rests (straws, leaves, potatoes tendrils, beans etc.) so that it could daily ensure about 100 kg of raw material, at which is added about 100 l of water and using a fermentation tank of 10 m^3, there can be obtained a quantity of approximately 4.5 m^3 / day of biogas at a pressure quantity of 150-200 millimeters col. H_2O. The raw material supply can be performed daily or periodically, by 3-5 days after the installation was exploited (started). The biogas is produced over 15 days. Subsequently, in normal operating conditions, the production is daily, the biogas quantity being correlated with the raw material one, introduced in the fermentation cabinet.

If in the fermentation room there is accumulated an important quantity of solid inert material (mineralized mud, sand, etc.) this is being evacuated manual (approximately once a year).

Constructive types: used construction materials. Fermentation cabinet's can be made for volumes of 5, 10, 25 m^3. They can be made of concrete, of a rectangular (10 and 25 m^3) or circular form, of ferro concrete pipes, being foreseen with multifunctional metallic bell for biogas accumulation (5, 10, 25 and 50 m^3). For zones with multiannual average temperatures of 12 °C there is absolutely necessary the external walls thermal installation and of the plate in order to maintain in the fermentation tank's interior temperatures that would permit the development of the fermentation process. A reasonable thermal installation can be ensured by masonries without mortar, with straw bales tightly covered with polyethylene. Depending on the local possibilities and on the available funds there can be chosen also solutions of thermal installation with classical materials.

In order to improve the efficiency, the rectangular fermentation tank can be covered by manure (manure and straws) which by composting release heat, thus ensuring a greater reaction speed in the piscine. Considering the circular fermentator, in order to ensure a related efficiency in the cold periods, there is recommended that the whole installation to be protected by an easy construction covered by a thin sheet of polyethylene, which would ensure the greenhouse effect.

The fermentation cabinet's can be placed in the owner's yard or in a place comfortable for more users in case of some greater capacities of the installations.

For zones with phreatic waters, there would be more proper the underground solution, meaning locating the fermentors in a foundation plate or can be semi-buried, with supplementary protection by the earth coverage.

It should be noticed that these fermentors ensure the biogas production accumulation, operate continuously during the whole year period, is feeded easily, don't require a continuous and qualified supervising and neither electricity consumption.

B) An approximate calculation of recoverable caloric energy in a formers husbandry by anaerobic fermentation of animal dejections.

Example: A farmer holds in his husbandry 25 cattle and 50 swine, using mechanical fermentation of dejections, in order to heat the leaving rooms.

The animal manure quantity is presented bellow:

The daily quantity of organic fermentable substance, will constitute:

- Cattle: $25 \cdot 4.9 = 122.5$ kg organic substance (o.s.) / day;
- Swine: $50 \cdot 0.45 = 22.5$ kg o.s. / day.

On the basis of these calculations, there can be assessed the average biogas production related to a duration of fermentation of 15 days, meaning:

- 0.275 m^3 / kg of organic substance for bovine manure and
- 0.485 m^3 / kg o.s. for swine manure.

The daily biogas production will constitute:

- from cattle $0.275 \cdot 122.5 = 34.512$ m^3 / day;
- from swine $0.485 \cdot 22.5 = 10.462$ m^3 / day or
- in total:44.974 m^3 biogas / day.

Considering the average caloric capacity of the biogas equal to 5,500 kcal / m^3 (that corresponds to a 65 % content of methane in biogas), we state that by its firing there can be obtained: $44.974 \cdot 5{,}500 = 247{,}357$ kcal / day, that is equivalent to 28.80 l of residual fuel oil / day.

The net thermal energy is calculated excluding the heat necessary for heating the fermentor and the heat losses.

For a retention period (fermentation period) of 15 days there is necessary a fermentation tank, having a volume of $(48 \cdot 25 + 5.8 \cdot 50) \cdot 15 = 22$ m^3.

If it's to consider the external temperature equal to 10 °C, for a loss coefficient of 0.7 there is achieved a daily loss value of

$$\frac{22 \cdot 0.7 \cdot (35-10) \cdot 24}{1.16} = 7{,}965 \text{ kcal.}$$

In order to heat daily of 1,490 kg of dejections, at a specific heat of 1.35 cal / m^3 degree there are necessary (the net boiler efficiency being 0.85):

$$\frac{1.35 \cdot 1{,}490 \cdot (35-10)}{0.85} = 59{,}162 \text{ kcal.}$$

Totally, in order to ensure the fermentor's operation there would be consumed about 27 % of biogas. For the husbandry necessities (heating, cocking etc.)

Dejection sources	Animal (poultry) weight, kg	Dejections kg / day	Organic substance kg / day
Dairy cattle	580	48	4.9
Feed up swine	90	5.8	0.45
Poultry	1.8	0.135	0.022

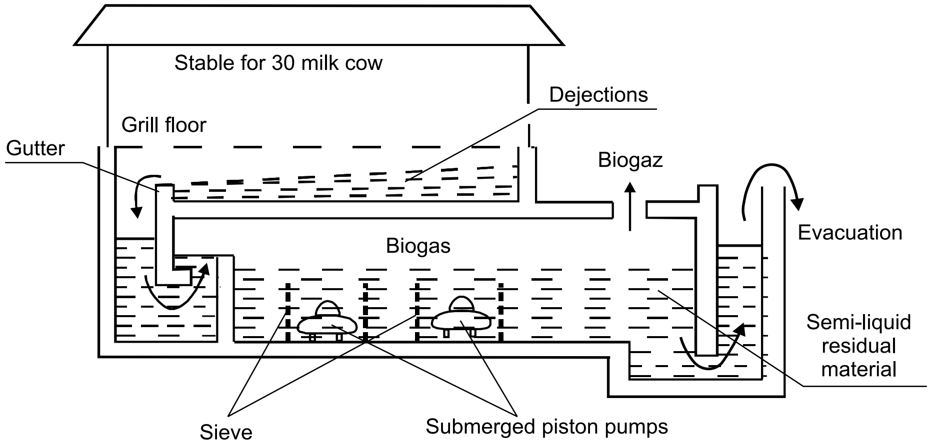


Figure 3.44. The scheme of an installation of biogass production

there still remain 247,357 – (7,965 + 59,162) = 180,230 kcal / day, energy equivalent to 21 l diesel oil/ day.

For a more precise calculation, there should be considered energy expenses for dejections pumping and mixing the fermentation tank content (*figure 3.44*).

3.3.2.3. Used waters and the sludge of the treatment stations

During the aerobic treatment of used waters, that is developing only in the presence of the process feeding system with oxygen aerating system of a high level energy consumption); there takes place the transformation of a considerable part of organic biodegradable substance which can be decomposed (by biotechnological methods) into another type of biomass, the one of treating bacteria, this one creating at its turn problems of further treatment, similar to the ones specific to the processing step of the treatment plants sludge.

In the process of anaerobic treatment of used waters there's consumed less energy (for maintenance of thermal regime in the fermenting tanks). At the same time there's produced biomass in excess (secondary sludge), only 4 % of organic biodegradable substance being transformed into sludge, as the anaerobic fermentation is accompanied by the emission of a gas mix fuel biogas (*figure 3.45*). Theoretically, at the fermentation of an organic substance equivalent to 1 kg of COD (Chemical Oxygen Demand), there's obtained 0.35 m^3 of methane.

It should be mentioned that by anaerobic fermentation it could be obtained the partial elimination of biodegradable organic matter, their decomposition being possible only by anaerobic biological treatment. Thus, after a preliminary anaerobic treatment it is necessary to foresee the aerobic treatment before the overflow into the used waters emissary. Therefore, it becomes advantageous to combine of anaerobic treatment of low energy consumption and without producing sludge with the aerobic treatment that ensures a good elimination of

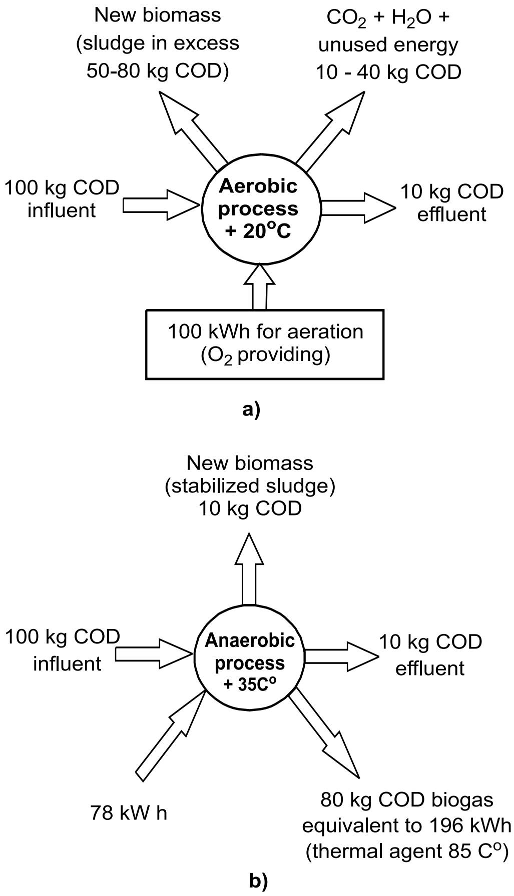


Figure 3.45. Energy characteristic of biological processes of aerobic treatment (a) and anaerobic (b) of industrial used waters

pollutants of the used and preliminary partial treated water. Considering the fact that by the anaerobic fermentation, depending on the used method, there can be obtained an elimination of 80-90% of the biodegradable substance, at the aerobic stage it follows to be decomposed only the rest of 10-20%, respectively with a low energy consumption and much less secondary sludge.

The industrial residual waters of a high content of biodegradable organic pollutants, like those of food industry, livestock leather goods, etc. can also be treated using advanced technologies of anaerobic fermentation by the help of fixed micro-flora. By the realized researches of T.U.M. there were obtained promising results presented in table 3.46. Thus, there is stated an efficiency of eliminating the organic substances of a 60-80% range, at a retention time from 0.2 to 3 days.

As it was mentioned before, in this domain there is proper the mixed treatment of used waters: aerobic – anaerobic. The advantages of such a treatment prove showing the example of a beer factory (*figures 3.46-3.48*) [64].

In order to exemplify the use of anaerobic treatment in a global plane, we present the diagrams of figures 3.49-3.56 [52].

The treatment of used waters leads to the retention and formation of some important quantities of sludge that incorporates as the impurities contained in the gross waters, thus those formed in the treatment processes.

The basic sludge sources and their treatment ways of the mechanical and biological scheme of used waters treatment – the most practical and spread all over the world – are presented in figure 3.57.

In table 3.65 there are presented several parameters of mesophyl anaerobic fermentation (at the operation temperature of 30-35 °C) of the accumulated sludge at the treatment plants of used waters and of the industrial sludge.

Table 3.64. Results of anaerobic treatment of liquid residuals proceeded from the duck growing (Poultry Factory of v. Bacovat) [55]

No.	Treatment temperature °C	Treatment duration, days	Initial COD of residuals, mg / m³	Treatment efficiency %	Total biogas production, l / day	Specific biogas production	
						m³/m³ by instalation	m³/kg COD
1	10	3.0	11,980	78.5	21.2	0.71	0.177
2	10	2.0	12,100	73.3	26.3	0.88	0.145
3	10	1.5	12,400	66.5	35.0	1.18	0.141
4	10	1.0	12,150	60.3	48.7	1.62	0.134
5	10	0.67	12,200	51.4	64.1	2.05	0.117
6	20	3.0	12,030	86.2	32.3	1.08	0.268
7	20	2.0	12,310	82.6	41.1	1.37	0.223
8	20	1.5	12,100	78.0	48.9	1.63	0.202
9	20	1.0	12,180	72.8	61.4	2.11	0.168
10	20	0.67	12,200	65.0	89.6	2.89	0.163
11	30	2.0	12,200	94.9	93.0	3.14	0.508
12	30	1.5	12,185	93.4	120.0	4.00	0.492
13	30	1.0	12,100	90.0	171.1	5.70	0.471
14	30	0.75	12,200	87.2	222.3	7.40	0.454
15	30	0.5	12,100	81.8	324.0	10.80	0.446
16	35	1.5	12,150	95.9	126.5	4.21	0.520
17	35	1.0	12,240	93.9	189.0	6.30	0.515
18	35	0.75	12,320	93.0	246.1	8.20	0.502
19	35	0.5	12,100	88.3	361.4	12.00	0.497
20	35	0.2	12,050	73.0	840.0	28.00	0.448

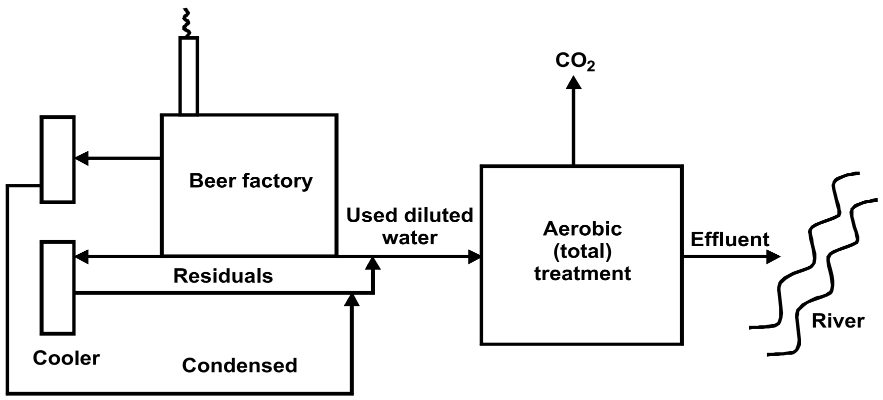


Figure 3.46. Conventional scheme of used waters treatment

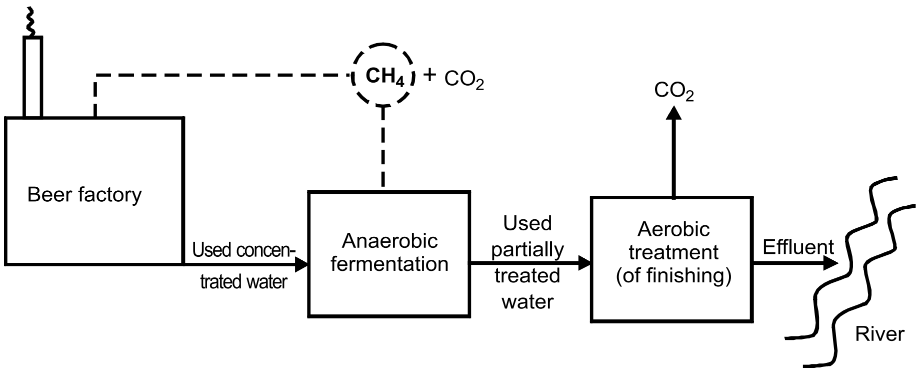
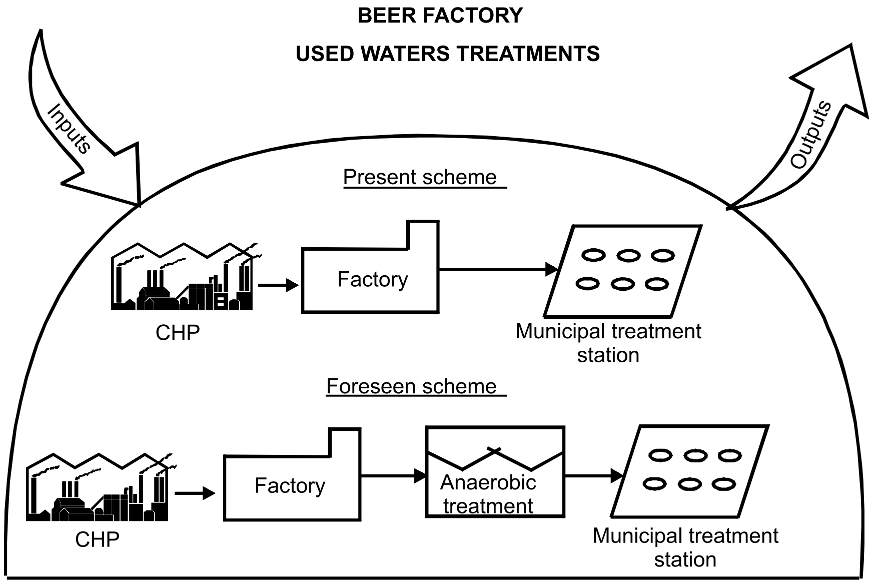


Figure 3.47. Anaerobic-aerobic treatment scheme of used waters



Inputs	*Present*	*Future*	*Savings*
Energy, thousands kWh/year	200	136	64
Gaz, m^3/an	37,750	32,080	5,670
Nutritive substances (N şi P), tons/year	610	0	610
Outputs			
Sludge (t d.s./year)	12.900	6.120	6.780
CO_2 emissions of CHP, t / year	107.400	72.900	34.500
CO_2 emissions of used waters treatment, t/year	187.000	165.000	22.000

Figure 3.48. The impact of anaerobic-aerobic treatment implementation on operation parameters of the beer factory

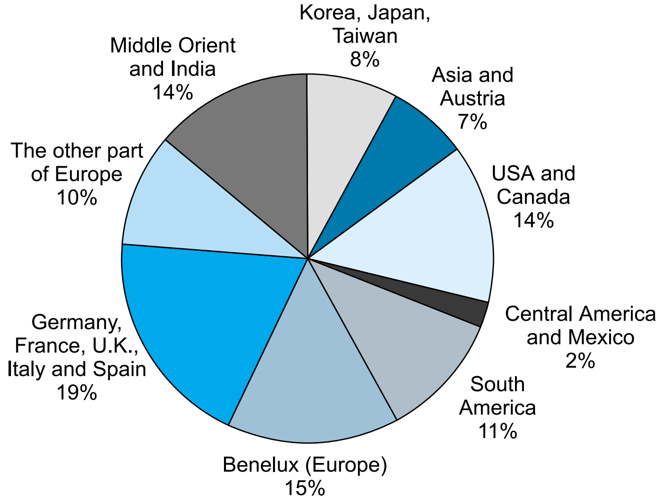


Figure 3.49. The distribution of anaerobic fermentation installations of industrial used waters in a regional aspect (total number - 599)

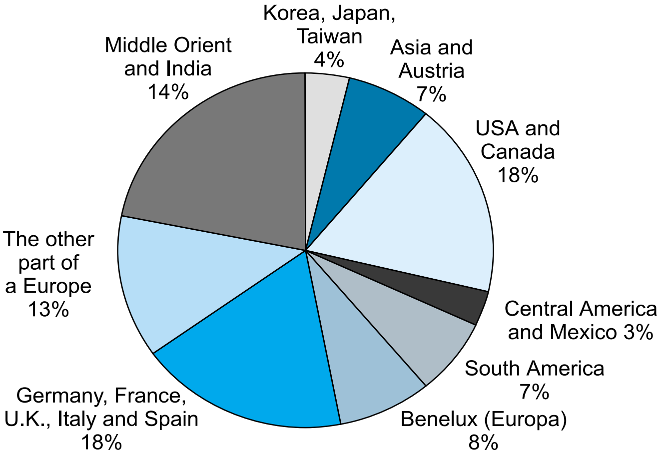


Figure 3.50. The distribution of large capacity installations for anaerobic fermentation of the used industrial waters in a regional aspect (total number- 234)

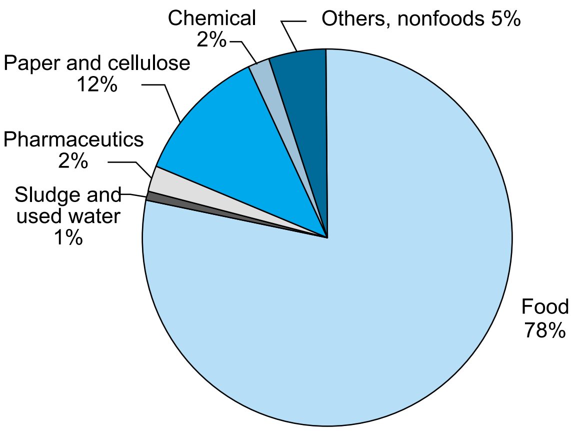


Figure 3.51. The distribution of anaerobic fermentation installations of used waters by types of industries (total number - 599)

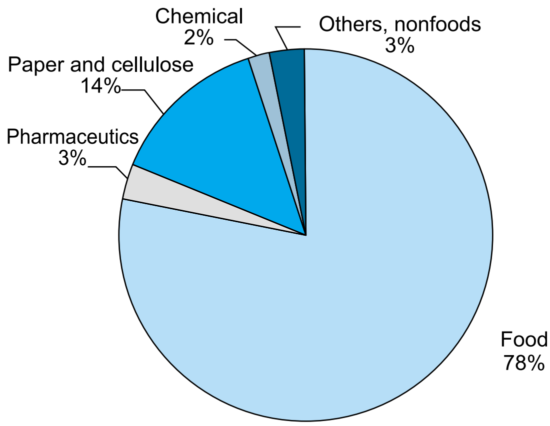


Figure 3.52. The distribution of great capacity installations for anaerobic fermentation of used industrial waters by types of industries (total number - 234)

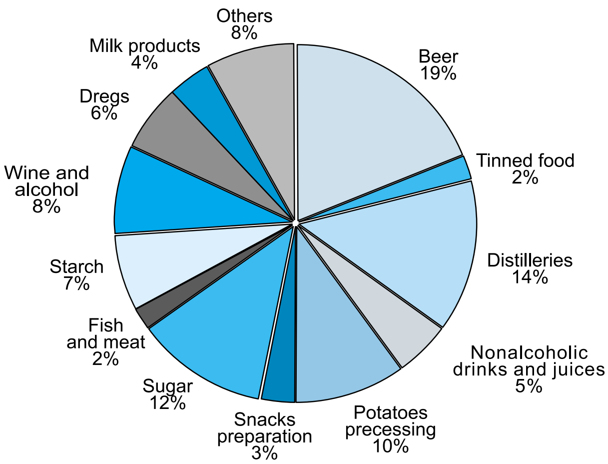


Figure 3.53. The distribution of anaerobic fermentation of used waters of the food industry (total number - 460)

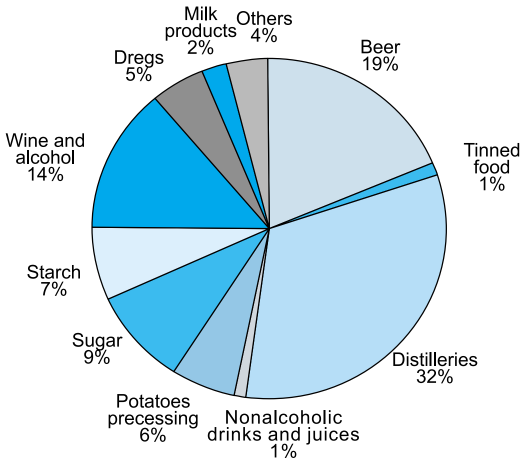


Figure 3.54. The distribution of great capacity for anaerobic fermentation of used waters of the food industry (total number - 139)

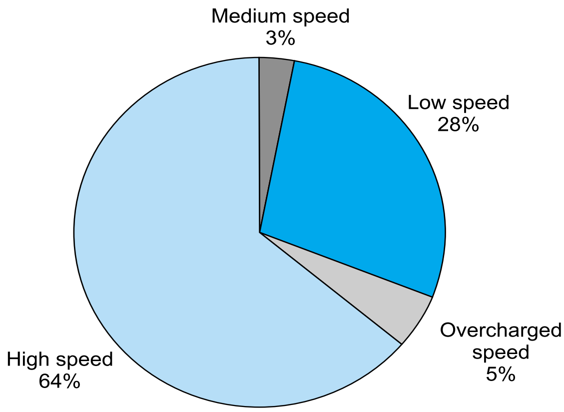


Figure 3.55. The distribution of anaerobic fermentation of industrial used waters depending on the utilized methods (total number - 599)

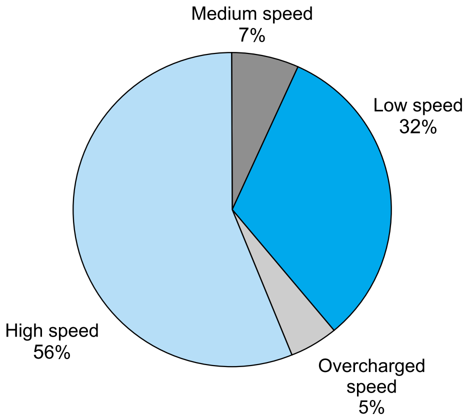


Figure 3.56. The distribution of great capacity installations of anaerobic fermentation of the used industrial waters, depending on the utilisated methods (total number - 179)

Table 3.65. Parameters of mesophyl sludge fermentation of the treatment stations [65]

Sludge Provenience	Organic charge degree, kg/m^3 day	Fermentation period, day	Mineralization, %	Biogas production, m^3 / kg organic substances
Basic sludge of the town treatment stations	3.0 - 4.5	10 - 15	56	0.49 - 0.52
Active sludge of the town treatment stations (mechanical and biological)	3.0 - 4.5	10 - 15	40 - 44.5	0.42 - 0.43
Mixed sludge of the local treatment stations (mechanical and biological)	3.0 - 4.5	10 - 15	45 - 50	0.4 - 0.5
Basic sludge from the spirits and dregs factory	2.0	10 - 30	60	0.6
Sludge proceeded from the slaughter houses	2.5 - 3.0	10	50	-
Basic sludge from swine farms	2.0 - 2.5	12- 15	50	0.5 0.6
Dejections from bull farms	2.5 - 3.0	15 - 20	50	0.2 - 0.3
Basic sludge proceeded from tanneries	2.0 - 2.5	20 - 25	-	0.34

3.3.2.4. Solid domestic wastes

If the anaerobic fermentation as a hygiene, deodorizing and sludge stabilizing process is applied on a large scale even by the 30's of the last century, the methanization of the solid domestic wastes has a much more recent history.

Of all the anaerobic fermentation technologies of the solid wastes, there can be mentioned the fermentation in a warm state (by diluting the residuals with water up to a 90 % humidity – figure 3.58); stocking the wastes in authorized places with the subsequent extraction of the biogas, using derricks after a conservation period (about 20 years).

The generating methane potential of domestic wastes storages is estimated at 62-125 m^3 / ton of dry substance of the total stocked residuals. In a period of 20-

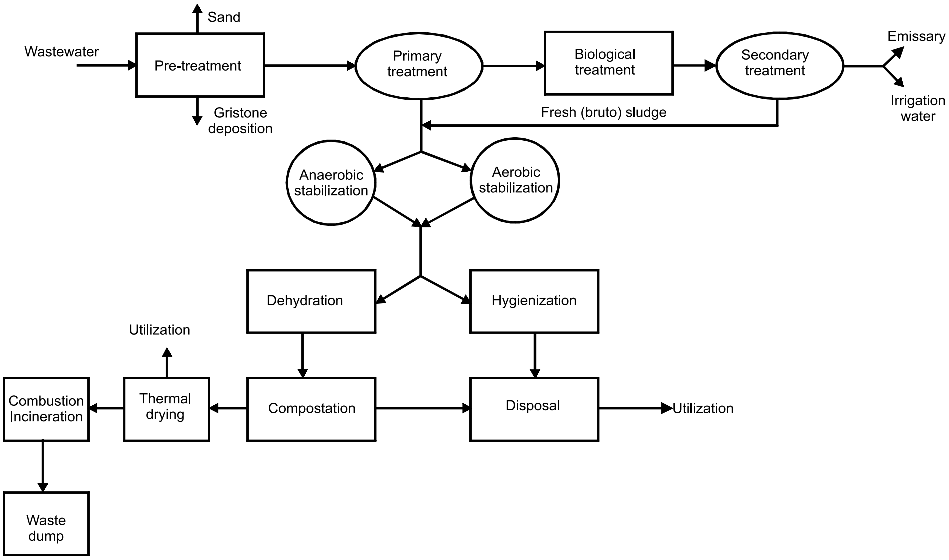


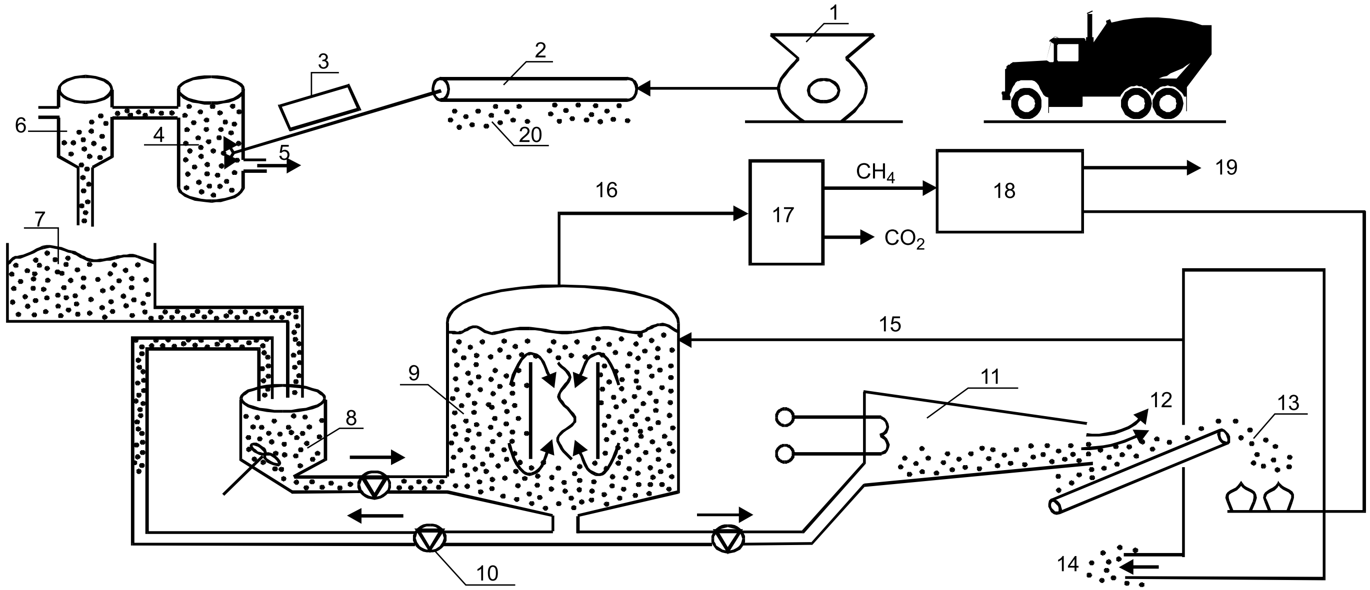
Figure 3.57. Sludge sources and treatment ways at the stations of mechanical and biological wastewater treatment

40 years from the storage, there can be extracted from the wastes storages using derricks 2.5-12.5 m^3 / ton of d.s. by year. From the accumulated gas in these storages there can be recovered from 50 up to 90 % biogas depending on several factors, including the distance between the derricks and their depth, as well as permeability of the storage coverage.

The solid domestic waste processing using technologies of their fermentation in a liquid state, known in West Europe as "Valorga" process is spread especially in the Netherlands and France. One of the most representative installations (Tilburg, Netherlands) operates since 1994 [66].

Thus, to the fermentation process there are subjected the solid domestic wastes with a content of dry substance of 40-51 %, including organic substance 36-60 %, intern particles > 0.5 min –8 ± 3 % of the dry substance, the basic component being the domestic wastes (38 %) and the vegetal rests (62 %). The installation itself includes:

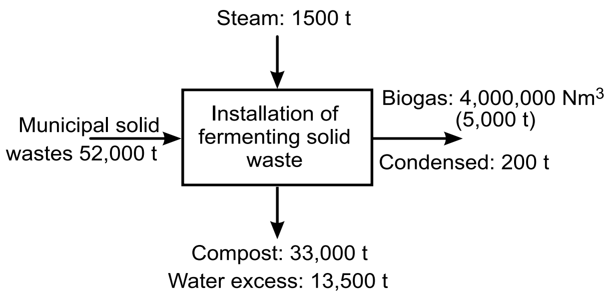
- Prepare section (reception, elimination of intern materials and grinding);
- Fermentation tanks (2 · 3,300 m^3) with equipment, for mixing, pumping, biogas accumulating, compression, evaluation and mechanical dehydration of the fermented material;
- Section of treating the liquid phase (clarifying the process water, its accumulation and heating); the greatest part of the water is reused for diluting the wastes and the surplus is ejected in the sewerage system;
- Composting section, which includes close reactions for solid material decomposition during 7 days and a stocking platform of the compost for a period of one or several weeks, from where is delivered to the consumers;
- Biogas husbandry (CO_2 and H_2S treatment, introduction into the municipal gasification system.



1 – Grinding
2 – Sorting / mechanical classification
3 – Magnetic classification
4 – Separating in ascending air flow
5 – Hard wastes (minerals)
6 – Cyclone
7 – Organic wastes storage
8 – Mixing basin
9 – Anaerobic fermentator (methane tank)
10 – Recycle of the fermented sludge
11 – Dehydration
12 – Usage of the dehydrated sludge
13 – Incineration
14 – Cinders
15 – Vapors
16 – Biogas evaluation
17 – Biogas evaporation
18 – Biogas reservoir (gas meter)
19 – Methane usage
20 – Dust, cinders

Figure 3.58. Scheme of obtaining of biogas from Solid Municipal Wastes

The annual material balance of the Tilburg installation can be presented as:



Average operation parameters of the related installation are presented in the following table:

Parameters	Measure units	Annual average values
Temperature	°C	37-40
pH	-	7.0-7.2
Treatment period	days	24
Oranic (volumetric) charge of the fermentators	kg d.s. volatile/m^3 ·day	7.0-8.6
Methane content in the eliminated biogas	%	56
Specific production of methane	Nm^3 CH_4 / t d.s. volatile	200-250

At the same parameters operates also the installation of Amiens, France, which was given in exploitation in 1998 and treats 55,000 tons / year of wastes in three fermentations, each by 2,400 m^3 (the installation capacity afford the treatment of 7,200 t / year).

The average biogas production is of 99 Nm^3 / t of row wastes or 146 Nm^3 / t of separate wastes of inert materials. During first 6 operation years, the installation produced 30,900,000 Nm^3 of biogas with a methane content of 54 %.

The annual balance of materials is:

Input : Solid domestic wastes (bruto) – 54,000 tons;

Output: Biogas – 526,000 Nm^3 (6,800 t):

Compost (organic fertilizer) – 22,100 tons;

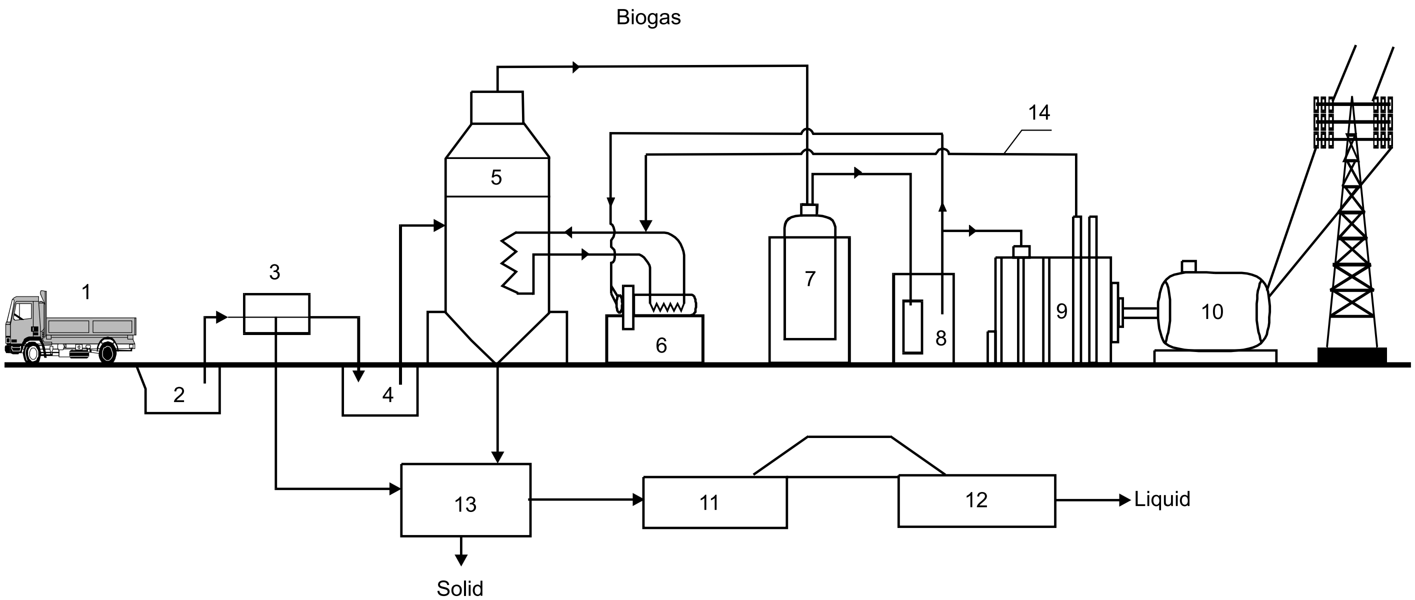
Combustible rests – 20,000 tons;

Glass, metal and other inert material – 5,500 tons.

3.3.3. Technological aspects of biomass anaerobic fermentation implementation

3.3.3.1. Systems and installations of anaerobic fermentation

Considering the conditions, which should be ensured for performing the organic substance fermentation, there is necessary that a biogas producing station, in the most complex form (figure 3.58) should comprise the following constructions, installations, equipment and apparatus:



1 – feeding;
2 – accumulating tank;
3 – separator of course material;
4 – homogenization tank;
5 – fermentator;
6 – thermal station for fermentator's heating;
7 – gasometer (biogas accumulation);
8 – biogas purification;
9 – internal combustion engine;
10 – electrical generator;
11 – biological ponds for liquid phase treatment (step **I**);
12 – biological ponds for liquid stabilization (step **II**);
13 – treatment of the fermented material (dehydratation, obliteration etc.);
14 - heat recovery of roast gas (escapement)

Figure 3.59. Biogas installation

- *Fermentation tanks*, which for a proper process development, must be tight, thermally isolated and endowed with systems or heating, recycling, and homogenized installations, biogas collecting devices, feeding installations with row material, installations of evacuating the fermented material, devices for test performing, for pressure and temperature control, as well as with devices of access in the fermentation tank for entertainment operations.
- *Installations for preparing and dosing the raw material* (the sludge and the used wastes) with a view to a proper feeding of the fermentation tanks, which consists in homogenizing tanks, sludge concentrators, installations for holding the coarse bodies or their grinding, pumps, debit meters and installations of automatic signalization the appearance of some inhibitive substances installations for correcting the chemical quality of the raw material, necessary to neutralize the inhibitive substances of the fermentation process or to its galvanization.
- *Collecting, transporting, purification and biogas stocking installations*, consisting of biogas collecting equipment from the fermentation tank, equipment for eliminating the condense, fire check, H_2S reducing installations, devices of biogas odorizing, compressors for biogas transportation or its injection into the fermentation tank, in order to homogenize the sludge, biogas counter, installations of biogas bottling.
- *Installations for biogas conversion into electrical and thermal energy*, respectively, thermal plants and energy groups of biogas conversion into electrical and thermal energy, necessary both for the technological requirements of the fermenting installation and for the employment of the biogas excess.

There are two possibilities of biogas recovery from the domestic wastes:

- treating the wastes at the appearance / their producing place – in small or individual installations;
- centralized treatment in installations of large capacity.

3.3.3.2. Biogas evolution as a fuel and its use

A) Biogas farm

The resulted biogas of the fermentation process of the organic substances contains CH_4, in different proportions, to which it's added CO_2 and small quantities of other gases, among which H_2S.

Alongside these, in the evacuated biogas of the fermentation tank, there are involved water vapors and sludge sprinkles.

The CH_4 relative density related to the air one 0.553 and the CO_2 ones – 1.529. The specific growth of CH_4 is 0.7 kg / m^3 and the one of CO_2 is – 2.0 kg / m^3.

Theoretically, the volumetric report of combustion air: biogas equals to 6. In reality, considering the CO_2 anti-combustion effect, the volumetric is comprised between 10 and 13.

The biogas firing speed is lower than 130 cm / s, therefore in order to ensure the firing, there should be performed several regulations at the burners, such as the reduction of the primary air access and the enlargement of the escapement orifices of the secondary air.

The biogas and air mixture in proportions comprised between 5 and 15 % is explosive and the CO_2 and the H_2S one are corrosive. At concentrations that exceed 0.001 %, H_2S, is perceived by smell and the doses greater than 0,1 are lethal [53].

The fermentation tanks operates at pressures between 150 and 350 mm H_2O column (15-35 mill bars), sufficient for burners feeding from the thermal plants and energy groups of biogas conversion into electrical and thermal energy, if these are placed at a distance of 200-300 m of the biogas producing plant. In order to prevent the appearance of the sludge sprinkles and the water vapors, the biogas extraction of the fermentation tank is performing by special devices.

For the situation in which the regime pressure is exceeded, there is foreseen also the security device, which is performed by a hydraulic closing of 400-500 mm H_2O.

The biogas transport toward the gas meter and the consumers is performed through zincked steel pipes, that ensure a proper tightness, are resistant to the corrosion and to the sun action, when these pipes are assembled in the slope toward the fermentation tanks and the emplacement points of the condense separators, in order to avoid the condense over them in the last.

Condense separators are usually emplaced at the base of the fermentation tanks, in the fireplace – in order to be protected of freeze.

As in the majority of cases the biogas can contain – continuous or intermittent H_2S, which is corrosive and very toxic, even in insignificant quantities, on the biogas pipes, especially on the portion just before the gas meter or before the usage points, there are foreseen devices for its elimination.

Both the biogas production and its consumption present daily variations even hourly. Therefore, the biogas producing plants should be endowed with reservoirs, called gasholders or gas meter, which would ensure the production and the consumption. The gas meter can be settled separately or in-group with the fermentation tanks. They can be made of metal, plastics and impregnated tissue.

For small installations and the individual ones, there can use also plastic bags, protected from the sun action, on which are laid the ballast elements (weights) necessary for use pressure insurance. The separate gas meters, with bell, beside the hydraulic guards, should be endowed with a relief pressure value, settled at a pressure smaller that the hydraulic closing one of the fermentation tank. As a supplementary security element, some installations are endowed with a biogas excess burner.

It is necessary, that alongside the gas analyzers and manometers, the biogas producing installations should be foreseen also with counters for measuring the biogas production.

As the biogas has no specific smell and there are possible some leakages in installations, it is obligatory to settle odorizing devices with alkyl hydrosulphide of the biogas evacuation pipes of the fermentation tanks, fact that permits the immediate perception of biogas losses.

If in the appropriation of the fermentation installation of organic residuals there is no plant that would deliver the necessary thermal agent, in order to ensure the fermentation temperature, it should be foreseen the construction of a thermal mini-plant as an attachment to the installation.

B) Biogas use

The biogas has a calorific power of 20-25 MJ / m^3 and can fully replace any type of fuel. At a normal report of 70 / 29 content of methane gas / carbon dioxide, 1 m^3 of biogas is equal to:

- 2.2 kg dry woods of beech;
- 0.54 l diesel oil;
- 0.52 l gasoline;
- 0.6 m^3 natural gases.

Lately, it's used also as fuel for transport means, thermal engines, turbines etc.

As follows, the biogas is used currently for heating, for electricity production in electrogenic groups and for motor vehicles engine feeding.

In order to increase the energy efficiency of the biogas installations, there were proposed the cogeneration technologies – of combined production of electricity and heat. Placing the heat changes into the coding liquid of the thermal engine and using a heating system that uses the escapement gases, there is recovered also a part of the heat emanated by the engine; this heat serves to the water heating, which ensures the optimal temperature in the fermentor.

The technical data regarding the operation and the electrogenic groups performances and of the mixed producing systems of electricity and heat, useful in the installations of anaerobic fermentation, feeded with organic residuals, are presented in [53] and in the professional literature.

The economic arguments prove that the biogas exploitment is pertinent, especially on the place of its generation, al least in present.

As it is possible that at some stations of biogas production, of medium and great capacity can appear in certain periods (especially, in the summer) biogas excesses, which can't be exploited in some zones, in such situation there would be indicated the biogas bottling installations, at a pressure of 150-350 bars. These installations would prove their utility as fuel for internal combustion engines at the communal transport means or at the tractors.

3.3.4. Economic, social and ecological effects of anaerobic fermentation of the organic residuals

3.3.4.1. Technical and economic assessment of the anaerobic fermentation potential of organic residuals

A) Agro-industrial wastes volumes

At this chapter there will be subdue to analysis, especially, the animal dejections and the manure.

In conformity with [40, 54], during 2000 the animal and poultry force, in all farm categories, constituted, as it follows (*table 3.66*).

Table 3.66. Animal and poultry population data in the Republic of Moldova at the end of 2000 year, thousand heads

Groups of animals and poultry	Total	Collective agricultural farms	Individual farmers
Bovines	394	83	311
including dairy cattle	269	38	231
Swine	447	165	282
Sheep and Goads	938	75	863
including sheep	830	75	755
Horses	71	16	55
Poultry	12,701	1,651	11,050

Considering the data of tables 3.58 and 3.59, the estimated calculation of the eliminated biogas at the anaerobic fermentation of the animal dejections indicates the following volumes:

Bovines – 79,170 m^3 / day · 365 days / year = 28,897 thousands m^3 / year;
Swine– 18,300 m^3 / day · 365 days / year = 6,679 thousands m^3 / year;
Poultries – 156,860 m^3 / day · 365 days / year = 57,254 thousands m^3 / year;

Taking into account the growth and maintenance kind of sheep and horses, it was considered that these should be excluded of the calculation. At the same time, because the number of animal and poultry heads is prevalent in the farms, more than a half of the year, these are being on the common, meaning outside the owner's yard, it was considered that only during a third of a year period, there takes place the animal dejection accumulation. Thus, the recovered biogas in the anaerobic installations will count to 19,116 thousands m^3 / year.

According to the experimental obtained data, in d. Braila, Romania [56] the average biogas production at the temperature of 17.5 °C in individual installations / farms constitutes 0.15 m^3 / m^3 fermentator. As 80 % of the livestock is being in individual installations and 20 % - in the collective sector, the necessary volume of the individual installations in the farms would constitute:

$$\frac{19{,}116{,}000 \cdot 0.8}{0.15 \cdot 365} = 279{,}320 \text{ m}^3.$$

The necessary volume of the average capacity installations in the collective agricultural farms maintaining the mesophyll thermal regime of fermentation) is calculated assessing the biogas production equal about to 1 m^3 / m^3 fermentator x day, that would mean:

$$\frac{19{,}116{,}000 \cdot 0.2}{1 \cdot 365} = 10{,}470 \text{ m}^3.$$

Considering the useful volume of the individual installations / farms of biogas in the limits of 10-50 m^3, their number can vary between 279,320 / 10 = 27,932 and 27,9320 / 50 = 5,590. In case of collective installations, having a useful volume between 100 and 500 m^3, their number can vary between 104,700 / 100 = 105 and 104,700 / 500 = 52.

B) Industrial used wastes of great organic charge

To this category of used wastes refers those proceeded of food industry enterprises: juice and alcoholic drinks factories, factories of tinned food, of milk, of sugar etc.

Considering the previous calculations (performed for 1995) [6], we state that at present the factories operate only a 1 / 3 of their capacity. The biogas recovery potential of the used wastes that proceed from the mentioned factories, thus being foreseen the anaerobic treatment only of the sludge resulted of the biological and mechanical aerobic treatment (the traditional scheme), is assessed at a volume of 40,260 m^3 / day.

As a result, there should be constructed fermentators of 1,000 m^3 volume each that constitutes 40,260 : 1,000 = 40 fermentators (methane tanks).

C) Sludge proceeds from treatment stations of localities with water feeding and sewerage centralized systems.

In republic, there operate 38 biological and mechanical treatment stations [6], the capacity of which, as a result of the economic crisis and of the water consumption countering, was reduced in average to 1/3. Installations of anaerobic treatment of sludge with biogas recovery (methane tanks) exist only at 5 treatment stations of used wastes (Chisinau, Tiraspol, Balti, Tighina and Cupcini). The rest of stations are endowed with open fermentators without collecting the eliminated biogas. Of those 5 stations endowed with methane tanks, none exploit these installations. As a result, the biogas is eliminated in the atmosphere from the drying platform surfaces, where there are stored the unfermented sludge (unstabilized).

The water consumption reduction as a result of counting the water feeding systems generated the decrease of the used waters quantity over flew into the sewerage system (almost 2 times), but not the sludge one, proceed from the used waters treatment, that have a higher polluting degree with materials in suspension, than usually.

In 1995, those 38 treatment stations of used waters had a potential of the biogas production of about 88,000 m^3 / day [6], the sludge flow being reduced by 1/3.

Thus, its quantity in the following years constituted about 60,000 m^3 / day. At a production of about 1 m^3 biogas / m^3 fermentation day, the total volume of the fermentors (methane tanks) should be of 60,000 m^3.

Considering the capacities of the existent in republic treatment stations, these methane tanks can be distributed in the following way:

20 methane tanks each by 1,500 m^3 = 30,000 m^3;
20 methane tanks each by 750 m^3 = 15,000 m^3;
60 methane tanks each by 250 m^3 = 15,000 m^3;

D) Solid domestic wastes

In conformity with [61], taking into account only the centralized waste collection, in 1998 the solid wastes quantity constituted 1,306,200 m^3, including domestic wastes in the town environment – 700 thousands tons. The volume of wastes stocked at the landfills of the republic, constitutes a stock of about 25-30 mln. m^3. As these landfills represent some unarranged fields, they can't be accounted at the assessment of the recoverable methane volume, because they have no nape that would ensure the tightness.

As for the future, there can raise the problem of developing a program of developing a program of separate collecting of solid wastes with a view to their recycling. Thus, over 15-20 years, in the related storages, there would be proper to place methane recovery wells.

$$700{,}000 \text{ tons / year} \cdot 20 \text{ years} = 14{,}000{,}000 \text{ tons.}$$

Considering that 35 % of these wastes are food rests, meaning of organic provenience, there result the following calculation:

$$14{,}000{,}000 \cdot 0.35 = 5{,}000{,}000 \text{ tons.}$$

The related quantity of food rests contains 40-50 % of dry substance.

Thus, the quantity of dry organic substance will constitute:

$$5{,}000{,}000 \cdot 0.5 = 2{,}500{,}000 \text{ tons.}$$

Knowing that the generating potential of methane of the domestic wastes storages is assessed between 62 and 125 m^3 / ton of organic substance (o.s.), we can state that the total biogas volume will be:

$$2{,}500{,}000 \cdot 62 = 155{,}000{,}000 \text{ m}^3 \text{ / biogas is 20-40 years or } 2.5 - 12 \text{ m}^3.$$

From this quantity there can be recovered from 50 up to 90 % of biogas. Thus, the total annual recoverable quantity of biogas counts to:

$$2{,}500{,}000 \cdot 2.5 \cdot 0.5 = 3{,}125{,}000 \text{ m}^3 \text{ biogas / year.}$$

Another way of biogas obtaining of solid wastes is the "Valorga" process, that consists in anaerobic fermentation in their liquid state. Those 700 thousands of tons which are accumulated annually in the town environment could be treated conforming to the used technologies in the installations of the Netherlands and France. The average specific biogas production in this process is of 99 Nm^3 / t of wastes, from which result that the total volume of biogas can be:

$$700{,}000 \cdot 99 = 69{,}300{,}000 \text{ m}^3 \text{ biogas / year.}$$

Using the related technology, a capacity of 1 m^3 of fermentor's volume, alow to obtain annually about 600 m^3 of biogas, from which result that the total volume of fermentor's would constitute:

$$69{,}300{,}000 : 600 = 115{,}500 \text{ m}^3.$$

For a type volume of 1,500 m^3 fermentor, their number will constitute:

115,500 : 1,500 = 77 methane tanks in total on the republic.

In the rural environment the solid domestic wastes and the animal dejections can be fermented together in individual or communal installations. Thus, the total recovered biogas volume from different sources of biomass, constitutes:

- Animal dejections – 19,116,000 m^3 / year;
- Used industrial waters of great organic charge – 40,260 x 365 = 14,695,000 m^3 / year;
- Sludge from the treatment stations of used waters 60,000 x 365 = 21,900,000 m^3 / year;
- Solid domestic wastes:
  - from arranged storages 3,125,000 m^3 / year

  or
  - by the wet "Valorga" process.

The total recovered biogas volume by anaerobic fermentation of organic residuals could constitute 125,011 thousands m^3 / year, that would equal to 62,500 t.o.e. / year. Due to these sources, there could give up on the fossil fuels. At the same time, it will be also obtained an environment profit, because the methane emissions will be reduced by 75 Gg.

3.3.4.2. Motivation of the necessity of implementing anaerobic fermentation technologies of the biomass in the Republic of Moldova

The accumulated sludge at the treatment stations of used wastes, as well as other wastes, constitutes an acute problem, solvable by their reintegration into agro-ecosystems, solution approved in a large range of countries. This reintegration on the agricultural fields imposes a special approach to the mentioned wastes that would satisfy the agro-technical and sanitary requirements.

The treatment methods of liquid residuals practiced all other the world are those become classical because they are successfully applied for years, these being: dickering, stabilizing, dehydration and disinfections.

By the stabilizing process of organic wastes, is being followed the decomposition of the biodegradable faction which can generate in unregulated conditions polluting effects. The stabilized effects contain also an important quantity of organic substance (about 50 %) than can be assimilated in humus, in case of their exploitment as fertilizer.

Usually, for stabilizing organic wastes, there is applied the biological method that consist in organic faction decomposition by bacteria specific to the aerobic environment. This process is called aerobic stabilizing (mineralization). In the case of the environment without oxygen it's about the anaerobic fermentation.

The present feasibility study was performed, hoping to promote the implementation of anaerobic treatment of sludge and organic wastes, even of the used wastes of great charge and to contribute thus to the environment protection.

Thus for the sludge fermentation, generated at the town treating stations and those of the animal dejections, there has been chosen the technology and the installations offered by SC IPROMED JSC, Bucharest and for the treatment of industrial used waters of great charge (food industry), being considered proper the technology elaborated by the authors of this study, using the fixed micro flora in the installations of anaerobic sunked filters [57, 58].

For organic sludge sources, like the town treatment stations of used waters and canneries, at the calculation basis there were considered the used waters flow, the concentration of minerals in suspension, as the Biological Oxigen Demond (BOD) value, depending on which there were determined the sludge flow resulted from the used waters treatment: basic primary sludge (resulted from the mechanical treatment) with the average humidity of 95 % and secondary or active sludge (resulted from biological treatment) with the average humidity of 98 %. For alcohol and sugar factories that doesn't dispose of treatment stations with traditional technologies (with the mechanical and biological step), there were accounted the flows of used waters of great charge, they themselves serving as source of biogas obtaining.

Because at the anaerobic fermentation the organic part of wasters is biologically degraded, which is partially transformed in biogas, there was also calculated the dry organic mass of dejections, which weight constitute 84 % at cattle of the dry mass of solid materials and 85 % at swine. For used waters of great charge the biodegradable substance content is expressed by the eliminated chemical oxigen demand values (COD) (see calculation for sugar factories).

It should be mentioned that in republic exists huge quantities of biodegradable organic wastes that pollute the environment. Thus, there weren't considered the animal dejections stocked in pits nearly the farms and zoo technical complexes, these constituting several millions of cubic meters – a polluting potential of phreatic waters and of the atmosphere and simultaneously an important quantity or row material for biogas obtaining and of natural organic fertilizers (after a proper treatment). The related category of wastes wasn't included in calculations, because during lots of decades, they have modified their properties being indicated as organic fertilizers.

Comparing their economic effects with the necessary expenditures for their elaboration performs the economic efficiency motivation of the measurement having as a goal the environment protection.

The index of comparative efficiency is determined using the following data: value of general employment expenses and capital investments, necessary for performing the protection measures of the environment, including the factor of investments recovery period.

In conformity with this methodology there were calculated the comparative efficiency indexes of expenses for anaerobic treatment installations and biogas producing, of a 250, 750 and 1,500 m^3 capacity. Data on biogas installations with capacities of 250-1,500 m^3 were offered by the Commercial Society IPROMED JSC, Bucharest (Romania), these serving as support (basis) for economic indexes calculations, presented in table 3.67 and 3.68 (exchange rate leu - $ USA – 12.87).

Information of the prices for 1 ton of NPK type fertilizer was offered by "Fertilitate" Society and that on the price of 1 Gcal of thermal energy – by the "Termocom" Association. The absolute economic efficiency of capital investments is determined by the report between the animal value of the economic effect and, minus exploitation and installation service expenses and the capital investment volume, that ensures the related effect.

The given variants were also examined in conformity with the feasibility study, signed by dr.ec.ing. E.Topală [59]. There was accepted the discounted rate i = 20 % and the inflation rate – 15 %.

In order to compare the variants in the case of 250, 750 and 1,500 m^3 there were calculated the total discounted cost (TDC) and the net present value (NPV).

Table 3.67. Characteristics of the biogas installations

No.	Technical and economic indexes	Measure unit	Total capacity, m^3		
			250	750	1,500
			Useful capacity, m^3		
			200	600	1,200
1	Total investment value, of which:	thous MDL thous $US	1,494.21 116.10	2,353.15 182.84	3171.17 246.40
	- Equipments	thous MDL thous $US	223.22 17.344	231.49 17.987	260.27 20.223
	- Constructions	thous MDL thous $US	962.88 74.816	1,813.55 140.913	2,602.79 202.237
	- Protection	thous MDL thous $US	290.09 22.540	290.09 22.540	290.09 22.540
	- Transport	thous MDL thous $US	18.02 1.40	18.02 1.40	18.02 1.40
2	Biogas gross production	thous m^3/year	91.00	273.00	546.00
3	Biogas net production	thous m^3/year	71.00	215.00	430.00
4	Total biogas production equivalent heat	Gcal	373	1,183	2,366
5	Net production value of biogas equivalent heat (325.86 MDL / Gcal)	thous MDL thous $US	121.55 9.44	385.49 29.95	770.98 59.90
6	Fertilizer production of NPK type	tons/year	5.05	15.0	30.0
7	Fertilizer production value, NPK	thous MDL/year thous $US/year	11.0 0.85	30.0 2.33	60.0 4.66
	Total incomes	thous MDL/year thous $US/year	132.55 10.25	415.49 32.28	830.98 64.56

Table 3.68. Annual exploitation expenses of installations for biogas production

No.	Economic indexes	Measure unit	Total capacity, m^3		
			250	750	1,500
1	Material consumption portable water (2.06 MDL/m^3)	m^3/an thous MDL/year	100 0.021	50,000 10.3	50,000 10.3
2	Material consumption electricity (0.65 MDL/kWh)	kWh/year thous MDL/year	3360 2.18	5400 3.51	7400 4.81
3	Pay-roll (4 persons · 500 lei/month· 12 months)	thous MDL/year	12	24	24
4	Social Insurance Quota (35 % of the pay)	thous MDL/year	4.2	8.4	8.4
5	Annual depreciation (20 % of the investments)	thous MDL/year	76.29	168.21	226.69
6	Other expenses (10 %)	thous MDL/year	9.47	21.40	27.4
	Total annual cost	thous MDL/year thous $US/year	102.82 7.99	232.36 18.05	297.34 23.10
	Payback period	years	50	13	6
	Coefficient of capital investments recovery	$years^{-1}$	0.02	0.08	0.17

The investments payback period (considering the inflation factor) will be:

for an installation with the capacity of 250 m^3 – 11 years;

750 m^3 – 6 years;
1,500 m^3 – 4 years.

The discounting of investment and production expenses, of gross and net income, means the use of a concrete value of i, settled a priori,– discounting rate. At its turn, the *i* rate can be treated as an economic efficiency index, called Internal Rate of Return (IRR).

IRR, as to the definition, express discounting rate that equals the discounted value of the total incomes and expenses for the entire study period. Thus, for the related variants:

- for installations of 250 m^3, corresponds IRR = 9.1 %;
- for installations of 750 m^3, corresponds IRR = 16.7 %;
- and for those of 1,500 m^3, corresponds IRR = 25 %.

It should be mentioned also the economic effect obtained as a result of the environment state improvement, of solving and using more efficient the natural resources, of substituting inorganic fertilities with the organic ones, obtained untraditionally.

This leads, at its turn, to the decrease of polluting and toxic substances in the atmosphere and in the aquatic basins.

The social effects include the improvement of the work and rest conditions, maintenance of ecological equilibrium (conservation of generic fund), maintenance of landscapes, of natural monuments, of natural reservations etc. The social effects can't be expressed in concrete produce is obvious. By the virtue of those mentioned above, we can conclude that: in the RM's conditions, the anaerobic treatment installations and biogas production with a capacity of 1,500 m^3 / year can generate annual earnings of 830,98 thousands MDL, that allows to recover the invested means in its construction in a period of 1.5 years. The installations with a capacity of 750 m^3 could ensure an annual income of 415.49 thousands MDL, thus recovering the investments in 6 years and those of 250 m^3 capacity an annual income of 132.55 thousands MDL, recovering the investment in 11 years. The absolute economic efficiency of capital investments constitutes, respectively, 0.17, 0.08 and 0.02, the social effects being indisputable.

The implementation of anaerobic treatment technology of agro-zoo-technology waste as well of the sludge from the municipal treatment stations of used waters and in the frame of enterprises of agricultural production processing, will lead to the liberation and to the recultivation of certain land surfaces, enough large, used as dumpsites, and to the prevention of soil erosion, to the environment protection etc.

The capital investments in projecting and constructing biogas installations are also very significant in the RM's conditions. Considering the present economic situation, these expenses can't be afford neither by the farmers, nor by the communal sector. It should be noted that the cost of 1 m^3 of biogas is so high (0.61-1.48 USD / m^3), that there can not exist any discussion on the competition of anaerobic fermentations, using traditional energy sources. In conformity with traditional methods of calculating the recovery period of capital investments (without taking into account the inflation rate), the expenses for installations of a 250, 750 and 1,500 m^3 capacity, can be recovered respectively in 50, 13 and 6 months, at very high exploitation indexes and with the condition of trading the fermented sludge as organic fertilizer, fact that at present can be accepted only theoretically.

From the environment protection point of view, the stabilization or the fermentation of liquid wastes is an obligatory condition, considering firstly the sanitary conditions.

Although, even if there would be respected the ecological conditions and the government quota will be minimum of 50 % of the capital investments, the implementation of biogas installations will develop during a relatively long period of time.

These remain to be two unsolved aspects of the related problem. First of all, there misses the methodic of assessing the economic prejudice caused to the environment by evacuating the unfermented dejections. Secondary, there is not approved or legalized the calculation method of the recovery period of the capital investments, considering the inflation rate (an inherent phenomenon of transition economy) and this fact does not support the investments in the related sphere.

3.3.5. Assessment of the environmental benefit and recommendations on the biomass energy implementation in the RM

3.3.5.1. General aspects

The application at the industrial scale of the anaerobic fermentation is relatively new, the treatment technologies being at the testing level. The anaerobic fermentation constitutes a process during which there takes place the organic residuals neutralization and at the same time the best way of preventing the air pollution, by reducing the methane emissions. There exists a certain number of parameters that depend on each country separately and that define the investment, exploitation, maintenance costs, like: residuals type (or their capacity), the quantity and the final usage of fermentation products, environment protection requirements, the cost and the complexity of the alternative treatment proceedings, the interest level etc. As a result, the installations that treat the same volume and type of residuals can lead to different costs in different countries. In the following table, there is presented a selection of the most important parameters.

At a preliminary and superficial analysis, there are underlined, as the most important parameters, the legislation and the electricity price. Saying in other words, the cost for the environment and health protection are not included in the present energy prices, but are supported with health risks, by the entire society and, in particularly by the future generations. Being internalized, meaning reducing the real energy price, they can drastically disfavor the present technologies of residuals treatment. As a consequence, the profitability of residuals treatment processes is conditioned equally by the political decisions and engineer solutions.

Table 3.69. The influence of certain factors on the capital investment value and on the operation cast of the anaerobic fermentors

Factors that influence the economic indexes	Influence on exploitation expenses	Influence on capital investment
Equipment type	Pre-treating Fermentators' type Biogas quality improvement Chemical reactive addition	Pre-treating Fermentators' type Biogas purification Biogas use Biogas storage
Capacity	Efficiency of electricity production	Economic balance
Profitability	Interest value Taxes Amortization expenses	Subsidies
Legislation	Post treatment Final products use	Post treatment Impact studies Security requirements
Living cost	Employment Insurance Transport cost	Employment Land cost
Residuals type	BOD (Biochemical oxigen demand) Content of toxic substances	Sources separation

3.3.5.2. *Assessment of the reducing potential of greenhouse gases as a result of biomass energy use.*

A) Considerations regarding different treatment process

There are three basic categories of fermentors: for solid domestic wastes, for liquid residuals (solubilizated) and used industrials wastes (animal dejections). The economic comparisons are justified only for the same type of residuals. In the bellow lines, we'll present a significant comparison between different proceedings.

Fermentation of solid domestic wastes. In the West Europe is practiced the source separation of domestic wastes, like metals, glass, polyethylene and other plastics, paper, organic substances etc. The goal of separate collection consists in recycling and reducing the wastes volume that follows to be stored or incinerated. Particularly, by eliminating the wet organic faction there is obtained the reduction of methane emissions of volatile organic compounds at the residuals stocking or the increase of caloric capacity at their incineration. In the European Community there is imposed a subsequent ban of this proceeding.

As to the settlement of certain rigorous requirement towards the treatment burning gases process regarding the content of CO_2, NO_x and considering the necessity of solidifying the ashes, the incineration becomes a very expensive proceeding. Thus, reducing the volume of organic action by wastes sorting at the source, there is obtained a cost reduction of their treatment.

The compost and the anaerobic treatment are those two methods of improving or neutralizing the organic faction of wastes. In the case of these proceedings result the humus of a high quality, which can be recycled in order to replace the peat import.

The main advantages of the anaerobic fermentation comparing with the compost are:

- Energy production;
- GHG reduced emissions;
- Smaller land surfaces for storage;
- Less emission with unpleasant smell.

The anaerobic compost application for solid domestic wastes treatment in a wet state lead to their compaction and to the limitation of oxygen transfer during the compost as a result, the compost can be late or even fail. Thus, the solid domestic wastes must be composed in close halls, with addition of dry organic material, which would favor the oxygen diffusion in the material subjected to the compost. From this reason, the compost trends to become to a certain extent a more expensive proceeding. But, in a Dutch study, performed in 1990, there is proved the opposition: the compost was cheaper than the anaerobic fermentation by 20-40 % in the limits of some quantities of 120,000 – 25,000 tons / year. It should be mentioned that this assessment is not typical. At the same time, at that period the anaerobic fermentation was not still largely applied at the solid domestic waste treatment and presented a relatively high degree risk factor.

These biological proceedings are less expensive that the solid domestic waste incineration. The example of Valorga installations prove an important investment

Table 3.70. Capital investments and operation costs for different treating technologies of used industrial wastes

System		Contact-reactor	UASB reactor	Fluidized layer	Contact-reactor	Aeration
Used water indexes:						
a) flows	m^3/day	6,000	6,000	6,000	1,600	1,600
	m^3/year	1,500,000	1,500,000	1,500,000	580,000	580,000
b) charge	kg/day	10,000	1,000	10,000	9,600	9,600
	kg/year	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
Capital investments:	USD	5,923,000	5,961,500	5,461,500	1,100,000	1,200,000
Operation and maintenance cost	USD/year					
a) capital		681,000	644,400	627,000		
b) exploitation and maintenance		115,000	96,000	105,000	52,000	300,000
c) energy consumption		-98,400	-130,000	-80,700	156,000	98,000
d) pay-roll		69,000	69,000	69,900		
e) others		443,800	444,200	439,200		
Total		1,210,400	1,123,600	1,159,500		
Specific cost	USD/m^3	0.8	0.74	0.77		
	USD/m^3 COD	0.48	0.45	0.46		

saving. The capital investments and the exploitation expenditures of the anaerobic fermentation installations have been reducing experience and to the growing competition.

B) Used industrial waters fermentation

The most largely used is the anaerobic fermentation as a first level of treating used industrial waters of great charge, particularly those of an chemical oxygen demand that does not exceed 2,000 mg O_2 / dm^3, in order to reduce substantially the cost of treating these waters. Usually, the anaerobic treatment is followed by the aerobic step, having as a goal the total treatment of used waters. Thus, 13 stations of Switzerland were built in the virtue of a more reduced cost of anaerobic-aerobic treatment. In one case, the anaerobic treatment was introduced into the technological scheme of the treatment station, in order to avoid the unpleasant smells that were spreading in the locality. The difference between the treatment costs by using different proceedings is minimal (*table 3.70*).

C) Agricultural waste fermentation

It is the case of industrial residuals or of the domestic wastes for anaerobic fermentation there exist alternatives that imply relatively high costs, the economic efficiency at the agricultural wastes treatment can be achieved only by the biogas production. Such advantages, like the quality improvement of fertilizing products or the reduction of the animal dejections impact on the environment, usually are not considered. As follows, the possibility of building economic efficiency fermentors is enough limited.

The majority of biogas existent installations are present in the swins nurseries, the dejections of these farms representing a considerable potential of biogas specific production. Less are the anaerobic fermentation cases of the cattle dejections. In Europe the cow farms are usually smaller. The typical biogas installations are foreseen for farmers with a number of 30-50 heads. It's considered that in order to be profitable, the investments in biogas installations should not exceed 750 USD by animal head. Therefore, in the majority of cases, the biogas installations are built by their own possibilities or a centralized, by the association of several stockholders. One of the cheep construction alternatives would their associating with the food industry enterprises.

In lots of European countries the biogas installations are subventioned by direct or indirect support, meaning by high price on the biogas produced electricity settling.

A great number of biogas installations of Germany and Switzerland have the recovery investment period under 13 years, period that coincides with the installations life period. Their profitability is ensured by the construction with the own powers, subventioning and, partially by busing industrial residuals. Taking into account the experience of biogas installations exploitation of Denmark, it is considered that the most profitable are the collective installations, respecting the following conditions:

- Using at least 15 % of the industrial residuals;
- Continuous biogas production, which could be used in installations with cogeneration and at high subventioned prices of electricity delivery;
- The raw material (animal dejections and organic residuals) should be situated not so far away;
- The installation's management should ensure low exploitation costs.

The authors of a recent study, performed in USA proved that the anaerobic fermentation in covered lakes and methane tanks with complete mixing, is profitable at investments of maximum 250 USD for 750 heads and at the most 400 USD for 300 heads of cattle.

D) Industrial biogas installations

In each village husbandry, there are accumulating daily wastes, which evacuation, destruction or use constitutes a serious problem. The usage of these materials for biogas producing constitutes a solution to this problem, thus being ensured both the energetic wastes exploitment and the obtaining of fertilizers of the fermented material.

The raw materials that can be used at the biogas and fermented sludge production – important source of humus – are different: animal dejections, agricultural residues, domestic wastes, human faeces etc.

The individual biogas installations are used for a long time period – hundreds of years – especially in countries with warm climate (China, India, Philippines etc.). the first place in the world at this chapter is hood by China, that have over 7 millions of such installations. Facing the energy crisis in the last 70 years, the government of India has initiated a special program of stimulating the exploitation in the villages of individual biogas installations, granting subsidies and credits to families that wishes to buy installations of a 2-3 m^3 capacity of biogas by day. But this campaign had not the expected result: of those 70 thousands purchased installations, about 70 % have not been operated. At a more detailed analysis of this situation, there have been stressed out the drawbacks of the related program:

- There were not considered the social economic prevalent formation, the cultural traditions of the village people;
- The population was not informed sufficiently on the technical aspect of the anaerobic fermentation processes; the majority of people were believing in the myth about the "miracle" of biogas producing of wastes, for free, without no effect;
- Lack of qualified specialists.

Such a program also failed in Romania, being imposed by decree, during the Ceausescu leadership. Considering the fact that the existent mentality at the time of Former Soviet Union still persists, its hard to believe that the population from villages will give up so easy on the collectivism.

At the same time, it's necessary to respect the following conditions:

- The installations is enough large, it must be tight and thermally insulated, meaning it requires a qualified execution;
- The feeding is performed regularly and the smaller is the fermentor's volume, the more often it should be done;
- The anaerobic fermentation takes place more intensively at higher temperatures and in a liquid environment, with a content of dry substance that does not exceed 10 % (humidity $>$ 90 %); this requires waste dilution with water, preferable warm, especially in winter;
- The anaerobic fermentation is performed by bacteria that decompose only the organic substance: it's not desirable to introduce in the fermentor inert material contained in the domestic garbage and it's excluded to have toxic substances.

Lower, there is given an example of measuring the useful fermentation volume of the individual biogas installations, for a farm that comprises:

- a 4 persons family;
- a well insulated dwelling, composed of 3 rooms, having, respectively, surfaces of 12, 16 and 18 m^3 and the height of 2.6 m.

In the winter, there are heating the first two rooms during 6 hours by day.

In winter conditions, the bathroom is used once a week.

At the settlement of the installation's dimensions there should be considered the following indicators:

- raw material assets;
- biogas necessary;
- money available funds for installation's establishment.

The farm disposal of: 1 milk cow, 1 calf; 2 hoggers, 20 laying hens, vegetable rests (straws, leaves, potatoes and beans tendrils etc.), faeces.

The biogas necessary is calculated for a winter day, when its consumption is maximal.

For cooking there are used the common gas stoves, with 2, 3 or 4 rings, with / without oven.

For different culinary operations, the necessary biogas is:

- for boiling: 0.2 – 0.24 m^3 / hour;
- for frying: 0.18 – 0.44 m^3 / hour;
- for baking: 0.18 – 0.46 m^3 / hour;
- for grill: 0.18 – 0.2 m^3 / hour.

In order to simplify the calculations, there was established the daily biogas necessary (for cooking) for a person:

- 1 person: 0.4 – 0.45 m^3 / day;
- 3 persons: 0.35 – 0.40 m^3 / day and person;
- 3-4 persons: 0.33 – 0.35 m^3 / day and person;
- 5-6 persons: 0.30 – 0.33 m^3 / day and person;
- 7-10 persons: 0.25 – 0.30 m^3 / day and person.

The necessary biogas for heating the dwelling can be determined with approximation, taking into account the data of table 3.71.

The necessary biogas for heating the water, including for bathroom, can be determined in conformity with table 3.72.

Thus, the necessary biogas will constitute:

- for cooking: 4 persons · 0.34 m^3 / person day = 1.36 m^3 / day;
- for heating: (12 + 16) m^3 · 2.6 = 73 m^3 heaten volume; 73 m^3 · 0.023 m^3 / hour · 6 hours / day = 10 m^3 / day;
- for bathroom: 2.3 m^3 / day once at 7 days = 0.33 m^3 / day.

Total daily average necessary = 11.69 m^3/day

Table 3.71. Necessary biogas for heating the dwelling

Construction characteristic	Necessary biogas for heating	
	m^3 / m^3 hour	For 10 hours of heating m^3/m^3
I. Dwelling well thermally insulated	0.021-0.025	0.21-0.25
II. Dwelling of a medium quality thermal insulation	0.023-0.027	0.23-0.27
III. Dwelling poor thermally insulated	0.035-0.038	0.35-0.38

Table 3.72. Necessary biogas for water heating

Way of heating the water	Number of family members			
	3	4	6	8
Directly on the burner	1.6	1.9	2.7	3.6
In boiler, including the bathroom	1.9	2.3	3.3	4.3

Table 3.73. Dejections quantity that can be obtained from different species

Species	Dejections, kg/day					
	Permanently in the stable			day – pasture; night – stable		
	Faeces	Urine	Total	Faeces	Urine	Total
Dairy cattle	20-30	10-15	30-45	10-15	5-7	15-22
Feed up bulls	18-21	7-9	25-30	9-10	3-5	12-15
Feed up calf	10-22	4-8	14-30	5-10	2-4	7-14
Saws in pregnancy	3.6-4.0	7.4 8	11-12	-	-	-
Feed up swine	6-7	11-12	17-19			
Breading swine	1-1.5	0.7-1	1.7-2.5	-	-	-
Hogs	2.5-3.5	3-4	5.5-7.5	-	-	-
Horses	16-20	4-5	20-25	8-10	2-2.5	10-12.5
Sheep	0.5-0.7	0.5-0.7	1.0-1.5	0.2-0.3	0.2-0.3	0.4-0.6
Poultry	0.15-0.2	-	0.15-0.2	-	-	-

Table 3.74. Daily available raw material

Material source	Quantity, kg/day	Dry substance		Organic substance	
		%	kg	%	kg
1 Milk cow	40	14	5.6	11.6	4.64
1 Calf	25	14	3.5	11.6	2.9
2 Swine	2•6.5=13	13.5	1.75	10.9	1.41
20 Hens	20•0.2=4	27.5	1.1	20.5	0.82
Hashed straws (coverage)	8	86.5	6.92	80	6.4
Tendrils (hashed)	2	17.5	0.35	14.5	0.29
Human faeces	4•1.0=4	26.5	1.06	18.0	0.72
	Total 96		20.28 kg		17.18 kg

The daily available raw material is presented in tables 3.73. and 3.74.

Those 96 kg of material will have a content of dry substance of $20.28/96 \cdot 100\,\% = 21.12\%$, meaning a surplus of d.s. Thus, in order to achieve a content of dry substance of 10%, the materials should be diluted with water. The quantity that should be added is calculated as:

$$A = 90 \cdot \left(\frac{20.28}{10} - 1 \right) = 98.61\,(\text{kg}).$$

So, the total quantity of mixture that will be introduced in the fermentor will be:

$$96 + 98.6 = 194.6 \text{ (kg/day)}.$$

These mixtures have generally a density of 1,1 kg/dm^3, the volume being: 194.6kg: 1.1 $kg/dm^3 = 176.9 \sim 177$ l/day.

Admitting that the fermentation will proceed during the winter, in good conditions of thermal insulation, at +15°C in the fermentor and considering that the optimal retention period equal to 40 days, by the help of table 3.75. we'll obtain the useful fermentation volume of:

$$177 \text{ l/day} \cdot 40 \text{ days} = 7{,}080\,dm^3, \text{ mean } 7m^3.$$

At the temperature of 15°C at the retention period of 40 days, the specific biogas production being of 0.26 m^3/kg o.s., we'll obtain the total biogas quantity that will eliminate:

$$0.26\text{mc/kg o.s.} \cdot 17.18 \text{ kg o.s./day} = 4.46m^3\text{/day}.$$

Table 3.75. Biogas production at different temperatures biogas/mc 1 kg organic substance(o.s.).

Retention period (days)	Fermentation temperature (Celsius degrees)						
	10°	15°	20°	25°	30°	35°	40°
5 days	0.075	0.090	0.140	0.180	0.220	0.280	0.340
10 days	0.100	0.125	0.175	0.250	0.325	0.400	0.430
20 days	0.140	0.180	0.250	0.330	0.370	0.420	0.450
30 days	0.170	0.220	0.300	0.360	0.400	0.425	0.450
40 days	0.185	0.260	0.325	0.370	0.400	-	-
50 days	0.200	0.270	0.340	0.380	-	-	-
60 days	0.210	0.275	0.340	-	-	-	-
70 days	0.215	0.275	-	-	-	-	-
80 days	0.215	-	-	-	-	-	-
90 days	0.215	-	-	-	-	-	-
100 days	0.215	-	-	-	-	-	-

Because the type fermentors are only of 5, 10, 25 and 50 m^3, we'll choose one having a capacity of 10 m^3.

In this case the real retention time will be: 10,000l/177l/day=56 days. By the help of fig. 3.75. we can state that the specific biogas production will grow to 0.28mc/kg o.s. As follows, the biogas production will constitute:

$$0.28\ m^3/kg \cdot 17.18\ kg\ o.s./day = 4.8\ m^3/day.$$

There can be stated that this volume is lower than the necessary biogas, initially calculated. In such a situation, exist two solutions:

- The biogas will be used for cooking, water heating and heating only the 12 m room.
- The dejections can be taken from neighbors, thus supplementing the quantity of organic substance in the fermentor.

In order to assess the cost of an installation, there is presented the material consumption in the case of a cylindrical installation of ferro-concrete with floating metallic bell for biogas accumulation.

Installation dimensions:

Capacity, m^3	Diameter, m	Basin depth, m	Bell's height,m
5	1.5	3.0	1.22
10	2.0	3.0	1.32
25	3.0	4.0	2.40
50	4.0	4.35	3.0

Materials	Installation's volume m^3			
	5	10	25	50
Cement, kg	1,050	1,670	4,100	6,200
Steel-concrete, kg	56	75	300	440
Sand, m^3	2.4	3.5	9.5	21
Gravel, m^3	1.5	2.6	7.7	13
Ballast, m^3	1.4	2.0	6.8	11
Tin, kg	113	201	970	
Metal elements, kg	25	40	51	76

E) Energy and legislation on environment protection.

The legislation has the strongest impact on the applicability of the anaerobic fermentation technologies: the more severe are the requirements towards the environment protection, the higher are the costs of the traditional processes. As follows, the more applicable is the anaerobic fermentation or organic residuals, because it's a "pure" technology.

For example, in Switzerland the burning gases emission standards and the requirements towards the storage of ashes and products, resulted from industrial eliminations, make the incineration extremely expensive. From this reason, in the related country the anaerobic fermentation of organic faction of wastes is an acceptable alternative.

The requirements for very clean compost after the anaerobic fermentation raise the cost for the separation of the component factions of wastes and impose a control, even after their collecting. The concentration of hard materials and other toxic substances must be strictly respected. It is indicated that the product should not contain plastics, glass, stones that ensures the fertilizer selling.

The gas emission standards become more and more strictly towards the NO_x or CO_2 concentrations, resulted from cogeneration, very often being imposed also the elimination of H_2S of the biogas. Usually, the legislation establishes also the selling price of the produced electricity. Thus, the high prices stimulate the biogas installations construction. In some European countries, such as Austria and Denmark, the heat production from by cogeneration is subventioned by the government.

Finally, the taxes for CO_2 or energy proceeded from the fossil fuels use, influence the biogas use profitability. Although, their impact remain minimal in comparison with the selling price policy, that is continuously raising. A real economic calculation will be possible only at the moment when the social cost will be internalized.

F) Social costs

The social costs include all the obligations/duties, uncovered by the energy buying price, meaning the trans-port risk, the impact on the environment etc. the greenhouse effect, for example, is caused by CO_2(50%) emissions resulted from energy producing(including the trans port circulation) of fossil fuels. The second considerable CO_2 source are the perhalocarbons(about 20%). There follows the biomass that also generates the greenhouse effect. The methane weight and of N_2O is almost 15%.

A recent study, performed in Austria proves that 32% of the total of 411 tons/ year of issued methane proceeds from solid domestic wastes storages, 7%- from animal accumulated dejections and 2.8%- from used industrial waters. All these sources can be prevented 40% of methane emissions.

If the governments would include the external cost in the energy price and would support the technologies that ensure the improvement of the environment state, by the added value/income, all the renewable energy sources would be used, without delay, at the global level.

Thus, although in Switzerland these social costs have been assessed, they were applied randomly only in the public constructions. It should be noted that the supplementary costs were intentionally underestimated (*tab.3.76*).

Table 3.76. Social cost of the energy in Switzerland [67].

Energy source	Present price(cents/kWh)	Social cost(cents/kWh)
Electricity	3.8-17	4.2
Oil	2.0-3.5	6.0
Oil (hard factions)	1.5-3.5	7.0
Natural gas	3.0-5.0	4.0
Woods	3.0-5.0	1.0

In any case, matters the fact that at leas, it has been tried to determine these costs, even with a certain approximation degree. The problem essence consists in the approval and appliance of the related costs by the enabled bodies, as well as by all those interested in.

BIBLIOGRAPHY

1. WasP 6.0, User's guide, Riso National Laboratory, 1998.
2. Troen I. and Petersen E.L., European Wind Atlas. Published for the European Commission by Riso National Laboratory, 1989.
3. Didger 2, User's guide, Golden Software Inc., 2000.
4. Dobesh H., and Kury G., Wind Atlas for the Central European Countries, Zentrabanstalt for Metrologic and Geolgasnic, Wien, ISSN 1016-6254, 1997.
5. Data base of periodical recordings of the wind speed and rose at the meteorological stations of the State Hydrometeo Service of the Republic of Moldova for 1990-1999.
6. T.Ambros, V.Arion, A.Gutu, I.Sobor, P.Todos, D.Ungureanu, Renewable energy sources, Publishing house "Tehnica-Info", Chisinau, 1999.
7. The industrial upsurge of Jeumont wind station.
8. Ubersich grober Anland sortiert nach Hersteller. www.windmesse.de/anlagenuebersich-gross-name.html
9. DeWind magazine nr.5/2001. Element. www.dewind.de/en/downloands
10. Wind energy barometer. Solar systems - 2001. pp.21-29.
11. Wind Energy. L.Jarass, L.Hoffmann, A.Jarass, G.Obermair. An Assessment of the Technical and Economic Potential. A case study for the Federal Republic of Germany, commissioned by the International Energy Agency. Springler - verlag. Berlin Heidelberg, New York, 1981.
12. Wind Power. Recent Developments edit by D.J. de Renzo, New Jersey, USA, 1979.
13. A.I. Shefter. "Wind energy utilization", Moscow, Energoizdat, 1983.
14. North Sea Offshore Wind - A Powerhouse for Europe, Technical possibilities and Ecological Considerations Study, Greenpeace.
15. Benjamin Dessus. Energy, a planetary defiance, Edition Belin, 1996.
16. Ministry of Energetics of the Ukraine, "Calculus of WES technical and economic indexes", Technical report, nr15-59, Kiev, 1998.
17. Bernard Chabot, Economic analysis of the wind energy, Liaison energy francophonie, nr.35, 1997.

18. A plan for action in Europe: Wind Energy - the facts, European Commission, Luxemburg, 1999.
19. Informational and analytical report, the Ukraine's Energetics: current state and development prospects, NTSEU, INED, Kiev, 1998.
20. Engineer's guide, Electricity tarification in France, fascicle D 4935.
21. Green book on the energy provision security. Technical document, European Commission.
22. Electrical power stations, nr.10, p.63-65, 1998.
23. I.I.Ilinih, A.B.Loze, West-Crimean and Donuzlav experimental and industrial wind electrical stations: Energetic construction, nr.3, p.55-62, 1991.
24. Solar energy guide. Solar energy at the service of the sustainable development. Under the supervision of Adelhanine BENALLOU and Jacques BOUGARD. IEPF, Quebec, Canada, 1996.
25. The European renewable energy study. Prospects for renewable energy in the European Community and Eastern Europe up to 2010. ECSS-EEC-EAEC, Brussels-Luxembourg, 1994.
26. Solar systems. Renewable energies observatory. March-April 2001, nr.142.
27. Solar systems. Renewable energies observatory. September-October1999, nr.133, May-June 2000, nr.137.
28. Solar drying of agricultural products in Europe. Thermie action program nr.SE22, 1996.
29. Solar systems. Renewable energies journal. March-April, nr.136, 2000.
30. Solar systems. Renewable energies journal. March-April, nr.142, 2001.
31. Solar systems. Energy-Environment-Development. March-April, nr.128, 1998.
32. John A. Duffie, William A.Beckman. Solar engineering of thermal processes. Second edition. New York: 1991.
33. Guide on USSR climate. Edition 11, Solar radiation, radiation balance and solar radiance. Leningrad, Gidrometeoizdat, 1990.
34. Guide on USSR climate. Edition 11, MSSR. Data for separate years. Part V: Clouds. Solar radiance. Solar radiation and radiation balance. Chisinau, 1979.
35. Scientific and applicative guide on USSR climate. Series 3: Long standing data. Part 1-6, Edition 11 - MSSR. Leningrad. Gidrometeoizdat, 1990.
36. Lasse G.F. MSSR climate. Gidrometeoizdat, Leningrad, 1978.
37. SNIP 2.04.01-85. Inner water pipe and sewerage.
38. Tarnishevskii B.V., Adekseev V.B., Kabilov Z.A., Abuev I.M. Solar traps and water heating installations. Teploenergetica, ¹6, 1995.p.48-51.
39. Statistical dictionary of Moldova. Special edition in for volumes. Department for statistical analysis and sociology of the Republic of Moldova. Chisinau, 1994.
40. Republic of Moldova. Statistical summary. Department for statistical analysis and sociology of the Republic of Moldova. Chisinau, 1994.
41. Republic of Moldova in figures. Concise collection of statistical information: 1998.
42. Statistic yearbook of the Republic of Moldova: 1997. Department for statistical analysis and sociology of the Republic of Moldova. Chisinau, 1998.
43. Luminosu, C.Popa - Luminosu, L.Popa - Luminosu. Energetic and economic study of a solar station with hot water accumulator used in a private household in Banat. National Conference "Installations for constructions and ambient confort", Ed.IX, Timisoara, 2000.
44. V.Arion, S.Codreanu. Basis of the technical and economic calculus of the transportation and distribution systems of electrical energy. Chisinau, U.T.M., 1998.

45. Technical prescriptions: PT MD 23-37429548-001.1999. Pumping aggregates.
46. Photovoltaic pumping: course handbook for engineers and technicians. IEPF, Ottawa University, 1998.
47. Photovoltaics in 2010. Vol.4: Micro and macroeconomics for sustainable policies on photovoltaics in Europe. EPIA. Bruxelles, 1996.
48. Technical agenda. Editura Tehnica, Bucuresti, 1990.
49. Z.A.Kats. Production of dry vegetables, potatoes and fruits. Moscow, 1984.
50. O.Burtea, Gh.Mihalcea, R.Cricoveanu. Utilization of solar energy for the dehydration of fruits and vegetables. Bucuresti, 1981.
51. First National Communication of the Republic of Moldova elaborated under the Framework of the United Nations Convention on Climate Change, Republic of Moldova, Chisinau, 2000.
52. Proc. Of Second Biomass Conference of the Americas: Energy, Environment, Agriculture and Industry, 21-24 August, Portland, Oregon, 1995.
53. Handbook of Biogas Utilization. Second edition, Atlanta, Georgia, 1996.
54. Republic of Moldova in figures. Concise collection of statistical information - 1998.
55. Technological necessities and development prospects. Report elaborated within the framework of the United Nations Convention on Climate Change. Ministry of Ecology, Constructions and Territorial Development, UNDP Moldova. Scientific editor V.Arion, V. Bobeca, Chisinau 2002, 176 p.
56. Non-conventional energies - superior and efficiently capitalized. Braila, 1986.
57. Ungureanu D.V., Ionet I.G., Sewage anaerobic processing using fixed micro flora. "Biotechnology", 1990. nr.2, p.48-50.
58. Ungureanu D.V., Ionet I.G., Anaerobic and aerobic purification of highly polluted sewage in installations with fixed micro flora, XXIX Conference "Equipments and installations systems '95", Sinaia, Romania, 1995, p.152-159.
59. Topala E., Fezability study. Elaboration principles. Economic and financial analysis of variants. Bucuresti, 1991.
60. IPPC, 1994, The 1994 Report of the Scientific Assessment Working Group of the Intergovernmental Panel on Climate Change.
61. "Moldova 21" - National strategy on sustainable development (version 1), Chisinau, 2000.
62. Vintila M. Biogas. Formation processes and utilizations. Ed. Tehnica, Bucuresti, 1989, 144 p.
63. Koberle E. Animal manure digestion systems in Central Europe. In: Proc. of Second Biomass Conference of the Americas: Energy, Environment; Agriculture, and Industry, August 21-24, 1995, Portland, Oregon, p.p.753-763.
64. Bers A.R. Bioenergy recovery systems for brewery wastewater management. In: Proc. of Second Biomass Conference of the Americas: Energy, Environment; Agriculture, and Industry, August 21-24, 1995, Portland, Oregon, p.p.724-733.
65 Ungureanu D. Bioenergy. In: Renewable energy sources. Ed.Tehnica - Info, Chisinau, 1999, p.p.281-394.
66. Saint Joly C., Morris S.A. Commercial operating experience with the Valorga Process in the municipal solid waste treatment field. In: Proc. of Second Biomass Conference of the Americas: Energy, Environment; Agriculture, and Industry, August 21-24, 1995, Portland, Oregon, p.p.744-752.
67. Wellinger A. Economic Viability of Anaerobic Digestion. In: Proc. of Second Biomass Conference of the Americas: Energy, Environment; Agriculture, and Industry, August 21-24, 1995, Portland, Oregon, p.p.830-839.

4. STRATEGIES AND POLICIES ENCOURAGING THE IMPLEMENTATION OF RENEWABLE ENERGY SOURCES IN THE REPUBLIC OF MOLDOVA

4.1. Experience of UE member states

The strategy and the policy of the EU member states concerning the implementation of renewable energy sources (RES) are presented in the White Book: *COM (97) 599 from 26.11.97 "Energy for the future: renewable energy sources – White book for a community strategy and action plan"*[1].

There's also an action plan exposed in this document stipulating that the quota of renewable energies in the gross energy consumption of the EU states should reach 12% by 2010. At present, this quota constitutes less than 6%. Hence, we rely on a large utilization of renewable energy sources: wind and solar energy, biomass. Since in the EU states to produce electrical energy approximately 40% of gross energy is consumed, the emphasis is put on the development of the electricity production from RES. In 2010 the weight of electrical energy coming from RES should constitute 22,1%.

At first sight, it seems that at least for a medium term, the electricity produced from renewable energy sources will be more expensive than the one coming from fossil combustibles. But this is a wrong impression because the environmental benefits and the state support granted to the traditional energetics are not taken into consideration.

After adopting the strategy on the development of RES, the EU countries have proceeded to the creation of RES support mechanisms and their harmonization in the community framework in the conditions of liberalization of the energy market [2]: *(Report to the Council and Parliament of Europe on the harmonization requirements. Directives 96/92/CE concerning common rules for the inner electricity market. JO nr. L 27/20 from 30.01.1997).*

The instructions stipulate only one stimulating mechanism to produce energy from RES exposed in the article 8, paragraph 3: *A member-state can lay claim to the system operator that when dispatching the installations generating electrical energy, priority should be given to renewable energy sources, sources functioning on waste or sources co-generating electrical and thermic energy.*

This stipulation represents an exception from the fundamental rule that is found in the same article 8, paragraph 2: *The choice of production equipments and the utilization of the interconnections are done on the basis of the criteria taking into account the economic priorities when producing electricity.*

The EU member-states have the right to treat differently the issue of RES supporting. From the big number of RES supporting modalities we'll specify the following:

- Obligation to guaranty the purchasing at a pre-established price of a definite quantity of electricity produced from RES;
- Exemptions from fiscal and other taxes;
- Subventions granting;
- Another financial support: for research and development, investments etc.

One of the most recent and important documents determining the policy of the EU member-states in this field is the Directive 2001/77/EC from September 27, 2001 regarding the promotion of the electrical energy produced from RES, on the unique energy market. This instruction traces out the following objectives that should be reached up to 2010:

a) doubling the contribution of the renewable sources in the total energy consumption, from 6% to 12%;

b) increasing the contribution of the renewable sources from 14% to 22% in the gross consumption of electrical energy.

We'll mention further down just some examples of materialization of the RES implementation and supporting strategy in the EU countries:

- French program HELIOS 2006 [3] (Solar systems. September – October 1999, nr.133), according to which there will be set up 50 000 individual solar installations for water heating, 25,000 m^2 of solar traps for dwelling space heating. The financial aid granted by the state for an installation with a trapping area of the solar energy of 2-3m^2 constitutes 4,500 FF (634 $USD), and in the case of an installation with a trap having an area of 5-7m^2 this support runs up to 7,500 FF (1,056 $USD). In addition, the community can offer a supplementary bonus, so that the financial support covers 50% of the total cost of the installation.
- German program "Solar na klar – solar, e clar" [3] that foresees, by 2003, an area of 2.4 million m^2 of solar traps installed annually and a total area of 55 million m^2 – in 2010. the program is patronized by the German Chancellor Gerhard Schröder and the minister of environment Jürgen Trittin, having a budget of 4.2 million $USD.
- French program EOLE 2005 [4] which goal is the installation of 500 MW of wind power up to 2005. In December 2000 they decided (Solar systems. September-October, 2001, nr.143) to oblige the French electricity administration EDF to buy the electricity produced by the wind installations with a power of 12 MW at least for a period of 15 years. The acquisition price for one kWh varies between 55 and 20 cF (0.99-0.36 MDL) depending on the wind potential in that region.
- Over 100,000 Danish families are shareholders of wind cooperatives [5] (Solar systems. January-February, 2001, nr.141). Promoting the so-called bonus policy, the Danish state has given the farmers from

the west part of the country, the poorest one, but with a pronounced wind potential, a joint interest to invest in wind farms. The produced electricity is bought at a fixed price of 0.053 Euro (63 bans) per kWh. A share is equivalent to 1,000 kWh per year. The net income makes 71 euro per year for a share that is not subject to taxation.

- In 1999 Germany launched the Federal program "100,000 photovoltaic roofs" for the 1999-2004 period. With the object of accomplishing this and other programs referring to the utilization of RES, the German parliament passed in February 2002 a new law on RES supporting [6]. According to this law, the acquisition price of the electrical energy coming from RES has increased as follows: wind – up to 0.178 DM (1.05 MDL); biomass – 0.2 DM (1.18 MDL); minihydraulic – 0.15 DM (0.89 MDL); photovoltaic – 0.99 DM (5.9 MDL).

4.2. The existing legal framework in the Republic of Moldova

In the energetic balance of the RM for the year 2000 [7] the gross consumption of energy sources makes $2{,}818 \cdot 10^3$ t.c.e., from which $19 \cdot 10^3$ t.c.e. or 0.7 % was produced at the hydroelectric power stations; $103 \cdot 10^3$ t.c.e. or 3.6% from wood and agricultural wood-waste. Thus, the own energy sources in the energetic balance of the RM constitute 4.3 %, all coming from RES.

Taking into account these incontestable realities, the RM should be a state in which RES are largely utilized. Unfortunately, it has been ascertained that during ten years of transition to the market economy there was too little done in this field. The traditional energetics specialists and the decision-making factors from the country do not take into consideration the 30 years experience of the EU countries for the elaboration of the strategy and policy concerning the promotion of RES, and, particularly, incentive measures for local producers and investors. However, there have been done some steps in this field, that denotes the desire of the decision-making factors to introduce RES in the country's economic circuit. Further on, we'll go through the recently passed documents referring – directly or tangentially – to the issue of RES utilization.

1. The law of the RM on energy conservation nr.1136-XIV from 13.07.2000 [8].

The notion of energy conservation has a large significance and, in the meaning of this law (art.1), is defined as *"organizational, scientific, practical, technical, economical and informational activity, with the purpose of rational utilization of the energetic resources in the process of extraction, production, processing, depositing, transportation, distribution and their consumption and attracting into the economic circuit of renewable energy sources"*.

The authorized body to administer the activity in the energy conservation field and, implicitly, RES promotion is the National Agency for Energy Conservation (NAEC) that activates in the framework of the Ministry of Energetics (art.5), being financed from the means obtained from provided services and the future National Fund for Energy Conservation (NFEC).

2. The energetic strategy of the Republic of Moldova up to 2010, approved by the Government Decision nr.360 from 11.04.2000 [9]. The strategic objectives of the national policy for the period up to 2010 are:

- Finalizing the privatization process of the energetic complex and creating the energy market;
- Promotion of the energetic efficiency, energy conservation;
- Assuring the state energetic security;
- Environment protection.

The accomplishment of the last three objectives also presumes "*the inclusion of the own energetic resources, including those renewable, in the consumption balance in cases when these prove to be competitive economically*".

The action plan (Annex nr.1) foresees the creation till 2010 of the Scientific, didactic and demonstrative center in the field of *energetic efficiency and renewable energy sources* (2003) and the adoption *of the Law on the utilization of renewable energy sources* (2005).

3. The Decision of the Government of the RM nr.1092 from 31.10.2000 [10] on RES utilization. This document is a first attempt to accomplish some foresights of the Energetic strategy of the Republic of Moldova. In the attached action plan it is foreseen to carry on a huge number of projects related to RES, and they are likely to be financed from "*the development funds and other funds created with the object of supporting the actions regarding energy conservation; from the income achieved form the difference between the cost of one energy unit obtained from renewable resources and one energy unit produced from mineral resources; donations of the international bodies*".

4. National strategy on sustainable development: Moldova XXI [11]. In the context of the sustainable development they foresee to achieve some objectives and actions in the energetic sector: *maximum utilization of the alternative energy sources; stimulation of the transition to decentralized energetic system, based on modern technologies of utilization of renewable energy sources (solar energy, wind energy, wastes etc.).* The action plan for the implementation of the Strategy objectives for 2001-2020 foresees:

- Introduction of RES in the consumption balance;
- Supporting the researches and informing concerning the utilization technologies of renewable energy sources;
- Launching some special educational and training programs with regard to energy conservation.

5. The first National Communication of the Republic of Moldova elaborated under the Framework of the United Nations Convention on Climate Change

[12]. The action plan in the energetic sector with a view to economize the energetic resources and reduce GHG emissions for the period of 2000-2010 foresees *the capitalization of renewable energy sources which would substitute 156.6 thousand t.c.e. in conformity with the minimum scenario or 969.4 thousand t.c.e. according to the maximum scenario of their implementation measures*.

4.3. Obstacles on the way of RES utilization

4.3.1. Institutional aspects

The legal framework described above denotes the existence of some positive indexes at the level of central public authorities concerning RES utilization. One can notice the Government's burning desire to include own energy sources in the economic circuit, speaking, in fact, about RES.

At the same time, we state that we don't have for the moment a well-defined state strategy with regard to RES implementation, similar at least with the one adopted in the EU countries [1]. In the above-mentioned documents they ascertain many declarative elements, without an institutional, scientific, financial support etc. Frequently, the principles stipulated in different documents are not harmonized among them. We'll enumerate here some essential obstacles:

- In the Law on electric energy [13] that regulates the relations among the participants on the electrical energy market *they do not specify the network access of the producers of electrical energy from RES and the state obligation concerning the purchasing of the electrical energy at a guaranteed price.*
- In the Energetic strategy of the Republic of Moldova till 2010 [9], in the compartment II "Strategic objectives of the energetic policy" it is mentioned that RES implication in the consumption balance is made in the case when these prove to be economically competitive. The respective thesis, formally faultless in the market economy, misleads both the potential investors in RES and the decision-making factors at the central and local level, since in the actual tariff for electrical energy *the expenses afferent to the fulfilling of environment protection requirements are not included. In addition to that, they also don't take into consideration other benefits as: creation of new labor places, especially in the rural area (the cost of one labor place is estimated at 12 thousand $USD [11]), reduction of import currency expenses, increasing the energetic security and others.* If these benefits are taken into account, the energy coming from RES will become competitive.
- The article 12 of the Law on energy conservation [8] "Facilities granted to the economic agents undertaking actions on energy conservation" provides *unequal conditions for local producers of energy efficient equipments and for those producing equipments for RES conversion, because the facilities are provided only for the producers of energy efficient equipments.*

- In the RM there is not an authorized body that would hold veridical and comprehensive data regarding RES potential. *The state doesn't dispose of the wind atlas and wind energetic cadastre, solar radiation atlas, catalogue of wood-waste coming from agriculture and forestry etc.*
- Up to the present, they did not approve the *National program of RES utilization*, the first project of which was elaborated in 1997 for the 1998-2005 period.

4.3.2. Educational aspect

The lack of the state policy in the field of *making the people aware vis-à-vis of the necessity of RES utilization* reduces considerably the efforts made with regard to implement these sources. The population of the RM has been educated in a society where the energy and other goods had low prices, not argued economically. Probably, removing this obstacle of a psychological nature will ask for maximum of time and efforts. The theme of the activities of making conscious of should vary depending on auditorium: adults, young people and pupils. It will be necessary to involve in these activities profile universities and NGOs.

At present, teams of researchers and engineers formed about 10-20 years ago in different domains – mechanics, electrical engineering, energetics, heat engineering etc. carry out the research and development workings in the field of RES. It is necessary to prepare young specialists through the organization of thorough post graduate and master courses.

4.3.3. Financial aspect

We stated above some examples from the UE countries concerning state supporting of the economic agents implementing RES. The Government of the RM does not have many possibilities to support financially RES users. At the same time, the decision-making factors from the RM should be aware of the following realities:

- *There is no country with a developed energetic sector that, at its time, did not invest massively in the traditional energetics and didn't subsidize fossil combustibles. Only after the 90's of the XX century, together with the launching in the developed countries of the liberalizing policy of the energetic sector, they raised the problem to reduce gradually and exclude totally the subventions.*
- *RES energetics develops following the same scenario. All countries that recorded notable results in the field of RES utilization support financially this domain.*
- *The international community, including financial institutions, support those states and governments that promote a policy assuring the growth of the energetic efficiency, RES utilization and environment protection.*

BIBLIOGRAPHY

1. COM (97) 599 from 26.11.97 "Energy for future: renewable energy sources – White book for a community strategy and action plan".
2. Report to the Council and Parliament of Europe on the harmonization requirements. Directive 96/92/CE concerning common rules for the inner electricity market. JO nr.L 27/20 from 30.01.1997.
3. Solar systems. September-October, 1999, nr.133.
4. Solar systems. September-October, 2001, nr.143.
5. Solar systems. January-February, 2001, nr.141.
6. Solar systems. March-April, 2000, nr.136.
7. Energetic balance of the Republic of Moldova in 2000.
8. Law of the RM on energy conservation nr.1136-XIV from 13.07.2000. Official Monitor of the Republic of Moldova, nr.157-159/1183 from 12.12.2000.
9. Energetic strategy of the Republic of Moldova up to 2010 approved by the Government Decision nr.360 from 11.04.2000.
10. Government Decision of the RM nr.1092 from 31.10.2000: On renewable energy sources utilization. Official Monitor of the Republic of Moldova, nr.141-143/1201 from 09.11.2000.
11. National Strategy for sustainable development: Moldova XXI. Economic Superior Council under the presidency of the Republic of Moldova. United Nations Development Program, Chisinau, 2000.
12. First National Communication of the Republic of Moldova elaborated under the Framework of the United Nations Convention on Climate Change, Republic of Moldova, Ministry of Environment and Territorial Arrangement, Chisinau, 2000.
13. Law on electrical energy nr.137-XIV from 17.09.1998.

Cover: *Daniela Cimpoiaş*
Computer processing: *Igor Bercu*

Publishing House “CARTDIDACT” CartDidact
111, V. Alecsandri St.
Tel. (+373 2) 241280
Printing House “RECLAMA”