Energy Situation and Alternatives in Romania

by

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1 Summary

The reason for this study is the discussion about the construction of the second unit of the nuclear power plant (NPP) Cernavoda. Since Romania wants to contract in the European Union it has started to adapt their legislation to the EU guide-lines. This led to a licensing process for NPP C2 similar to the environmental impact assessment required by the EU guide lines. The process was based on an EI study made by the National Institute of Research and Development for Environmental protection (ICIM) in Bucharest. The owner of the plant presented an environmental impact summary in english on its website. In this document we miss a proper discussion of the need of the project. In particular we miss the discussion of other options (including the zero-option) and the environmental impacts of the other options compared to the impact of the NPP.

Especially from the view of sustainable development – which is a declared aim of the European Union's policy - we think that there are better options than nuclear power for meeting the Romanian needs for energy services. These options are without the risk of disastrous accidents for the population, and dont generate longlasting radioactive waste. On the contrary these energy options provide new opportunities for the Romanian population: decreasing energy expenditure, new jobs and a clean environment.

In the last years an EC funded project proved once more that for remote settlements electrification by renewables is cheaper than to connect these houses to the national grid.

The paper we present here provides a survey of the options for the use of renewable energies in Romania and their potential compared to the output of the NPP C2. In order to replace the electricity generated by the NPP Cernavoda, there is no single action which guarantees the success. However an appropriate mix of measures carried out will lead to high efficiency in the energy consumption sector and to a sufficient production of heat and electricity for Romania.

Advantages and Disadvantages of renewablew energy[1]

Solar

Advantages: always there; no pollution
Disadvantages: low efficiency (5-15%); very high initial costs; lack of adequate storage materials (batteries); high cost to the consumer;

Hydro

Advantages: no pollution; very high efficieny (80%); little waste heat; low cost per kWh; can adjust kWh output to peak loads; recreation dollars
Disadvantages: fish are endangered species; sediment buildup and dam failure; changes watershed characteristics; alters hydrological cycle;

[1] http://zebu.uoregon.edu/2001/ph162/l1.html

Wind
Advantages: small scale; decentral, supplemental power in windy areas; alternative for individual homeowner and small villages;
Disadvantages: Highly variable source; relatively low efficiency (30%); more power than needed is produced when the wind blows; feeding into the grid or efficient energy storage is thus required;

Biomass Burning
Advantages: biomass waste (wood products, sewage, paper, etc) are natural by products of our society; reuse as an energy source would be good; definite co-generation possibilities; maybe practical for individual landowner;
Disadvantages: particulate pollution from biomass burners; transport not possible due to moisture content; unclear if growing biomass just for burning use is energy efficient; large scale facilities are likely impractical;

The most hopeful options for Romania are as follows

Efficiency Improvement
In November 2000 the national "law concerning the efficient use of energy" passed the Romanian parliament.

This law is a step in the right direction, but the realization of the huge potential requires the abolishment of subsidies for fuel, an active policy of dissemination of know-how, the promotion of the advantages of energy savings and an effective financing mechanism.

Wind power
Within the Romanian state program for energy it is planned to install wind power stations with a total capacity of 550 MW until 2010. In further future the installed total capacity should reach 3000 MW - this wind power capacity can replae at least two CANDU 6 units.
Since wind energy is traditionally established in Romania and some research units have built new and efficient plants, the wind energy option is interesting not only regarding to the production of cheap and clean energy, but it can also contribute to the development of a new industrial branch in Romania.

Solar power
With a solar radiation of 1300 –1500 kWh/m² Romania has a valuable potential for solar energy application. Moreover the country has made efforts to develop the solar energy equipment since 1979. Hot water systems as well as systems for drying and industrial application have been installed. Because of the poor quality of the equipment only a small part of these collectors are still in use. Nonetheless Romania has know-how about the installation and the use of solar energy collectors for various purposes.

To replace the total amount of thermal energy for district heating in Romania (62.000 TJ) by means of solar heating 43 km^2 collector area is required.

To substitute the 5400 GWh annual electricity produced by a CANDU 6 reactor approximately 30 km^2 photovoltaic panels are necessary.

Biogas

In order to replace the electricity produced by one CANDU 6 unit several small combined cycle biogas plants are necessary (e.g. 35 of the above described type). In order to supply the demanded amount of energy plants for the gasification 3500 km^2 farmland are needed, which is less than 2 % of the total area of Romania or about 30 % of today's arable area. During the integration process of the Romanian economy in the EU market, agrarian production will become more and more intensiv and parts of the farmland will become available for new processes. Energy plant generation is a new opportunity for these regions and the inhabitants.

Small hydro power

The total hydroelectric power potential is about 40 TWh per year of which 12 TWh per year have already been developed. There may be as many as 5,000 locations in Romania that are favorable for small hydroelectric power plants (<30 MW).

The yet planned projects achieve an capacity increase of 200 MW by refurbishing one big hydro power plant. This shows that the technical improvement of the existing 640 hydro power plants in Romania could increase the available capacity substantially.

Even if it is not sustainable to develop the total potential of hydro power, an ecologically sound development of a part of the 5000 favorable sites could be discussed.

2 Basic information and data

2.1 Climate, landscape, vegetation

Romania's climate is temperate-continental with oceanic influences from the west, mediterranean ones from southwest and continental-excessive ones from the northeast. Annual average temperature is 8°C in the north and 11°C in the south and varies with values of -2,5°C in the mountain areas (Omu peak - Bucegi massif) and 11,6°C in the plain (Zimnicea town - Teleorman county). Anual precipitations decrease in intensity from west to east, from 600 mm to 500 mm in the Romanian Plain and under 400 mm in Dobrogea and in the mountain areas they reach 1000-1400 mm.

Romanian running waters are radially displayed, most of them having the springs in the Carpathians. Their main collector is the Danube River, which crosses the country in the south on 1075 km length and flows into the Black Sea. In the mountain areas there are numerous glacial lakes and recently, anthropic lakes which turn into account the rivers hydro-energetic potential.

The vegetation is determined by the relief and by pedo-climatic elements, being displayed in floors. Mountain areas are covered by coniferous forests (especially spruce fir), mixture forests (beech, fir-tree, spruce fir) and beech forests. Higher peaks are covered by alpine lawns and bushes of dwarf pine, juniper, bilberry a.s.o. In the hills and plateaus there are broad-leaved forests, prevailing beech, common oak or durmast oak; the main forests species often met on low hills and high plains are Quercus cerris and Quercus frainetto. The steppe and silvosteppe vegetation, which covered the areas of low humidity in Dobrogea Plateau, Romanian Plain, Moldova Plateau and Western Plain has been mostly replaced by agricultural crops. [2]

2.2 Development of Population and their cost of living

Table 1: Population, cost of living and energy[3]

year	1996	1997	1998	1999	2000
population	22.619.000	22.545.900	22.507.300	22.472.000	22.443.000
cost for living [in Euro]	27	27	34	29	33
cost for housing, water, electricity and other fuels [in % of total]	13,4	12,9	14,9	17,6	19,2

A large part of the Romanian population (approx. 45%) lives in rural aereas. About 70,000 rural households are still not electrified. 40% of these are in the Western Mountains of Transylvania.

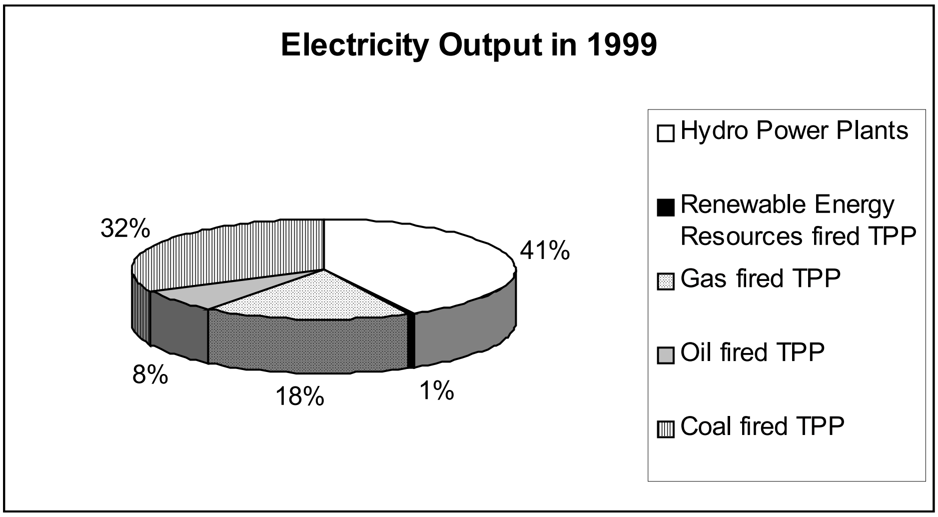
[2] www.fict.ro/romania.htm – Foundation for promoting Information and Communication Technology
[3] Statistical yearbook on candidate and south-east European countries (EUROSTAT – Statistical Office of the European Commission, 2002); chapter 1 and 4

General Characteristics of the Romanian Energy Sector

Table 2: Annual energy production and consumption in Romania[4]

	1996	1997	1998	1999	2000
Primary production – all products [in 1000 toe[5]]	33.856	30.367	27.890	26.811	29.630
Total primary energy supply – all products [in 1000 toe]	49.114	44.135	-	-	-
Final energy consumption (all products) by sector in 1000 toe					
Industry	13.680	12.089	9.679	8.044	10.208
Transport	4.077	4.205	3.920	3.147	3.541
Others	12.851	11.367	11.071	9.945	10.281
Installed electrical capacity [MW]	22.856	22.843	-	-	21.904
Electricity generation GWh	61.350	57.148	53.496	50.710	51.934
Output of Nuclear power plant [GWh]	1.396	5.400	5.307	5.198	5.456
Derived heat output from district heating plants (public and autoproducer plants producing heat only) [TJ]	81.588	76.788	89.572	70.760	62.454

Figure 1: Share of different resources in electricity production of Romania (Source; Report: The present situation in the energy sector in Romania)



The energy sector in Romania is still plagued by the specific problems faced by most countries in transition:

- low efficiency of energy production and usage;
- high marginal cost of energy production;
- poor legislative, institutional and regulatory infrastructure, plus administrative inefficiency leading to high transaction costs;
- increases in energy prices that consistently exceed the general rate of inflation;
- low collection rates especially from industrial users but also from individual consumers because of the high share of energy bills in total household expenditure;

[4] Statistical yearbook on candidate and south-east European countries (EUROSTAT – Statistical Office of the European Commission, 2002), Chapter 9
[5] toe – tonne of oil equivalent (conventional standardised unit defined on the basis of a tonne of oil with a net calorific value of 41.868 joules per kilogram)

- poor record on energy conservation and compliance with national environmental requirements.

These problems have been exacerbated by the poor performance of the economy - particularly over the past few years - high inflation rates and the low level of foreign investment. Since the political changes of 1989, the Romanian energy sector has benefited a bit from grants, loans and technical assistance programs from the international community. In addition to multilateral projects, several individual countries, notably Denmark, the Netherlands, France and the United States are active in the energy and energy efficiency field in Romania with bilateral projects. A significant proportion of those resources has been directed towards improving energy efficiency, thus to reducing GHG[6] emissions.

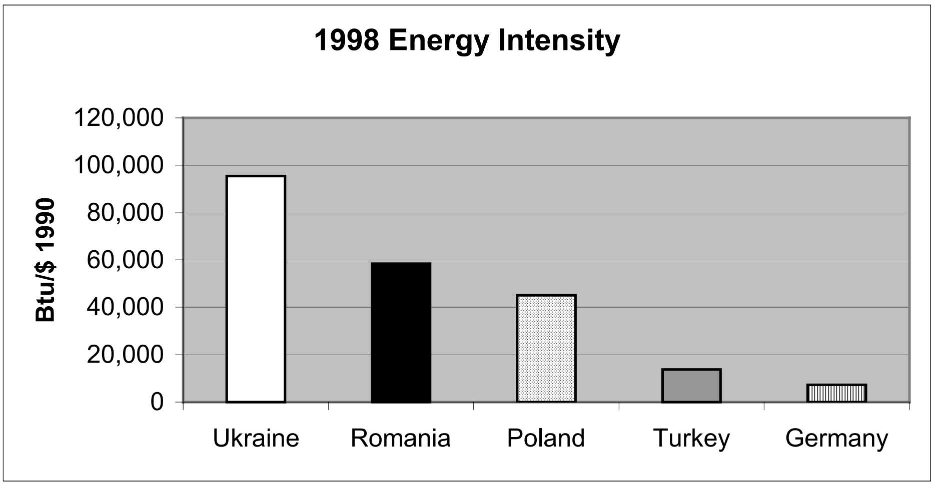
2.3 Energy efficiency in Romania

For years, Romania´s natural resources have been systematically exploited for the sake of promoting an industrial development with no regard to limits and costs in terms of environmental damage. The former governmental regime developed a highly industrialized economy, based on energy intensive industries, leading to high levels of energy consumption per unit of GDP[7]. Even now, while this situation is readily acknowledged, the solutions generally focus on increasing production output rather than promoting energy conservation principles. As a consequence Romania has reached considerably high levels of energy intensity - at least twice as much as in the OECD countries - which contributes greatly to the environmental pollution in Romania. [8]
Together with Poland and the Slovak Republic Romania is a transition country where the energy intensity of the industry remained constant, but that of the rest of the economy improved. These countries are characterised by a large share of heavy industry in GDP and the reluctance by their governments to tackle the politically delicate restructuring of these sectors.[9]

The potential for energy savings due to enhancing the efficiency is huge, as it is shown by the comparison of energy intensity in figure 2: The energy intensity in Romania is 8 times the one in Germany.

[6] GHG: Green House Gas
[7] GDP: Gross Domestic Product
[8] The regional environmental Center for Central and Eastern Europe, Bulletin: "Promoting energy efficiency in Romania" by Ioana Luca
[9] The energy intensity of transition countries; Cornillie Jan, Frankhauser Samuel; EBRD Working paper No.72, June 2002

Figure 2: Energy Intensity 1998 – a comparison (Department of Energy-Energy Information Administration) [10]



Romanian policy has acknowledged the importance of enhancing the efficiency in energy production in order to protect the environment as well as the health and welfare of the population. In November 2000 the national law concerning the efficient use of energy passed the Romanian parlament.

"The national policy for the efficient use of energy is an integrant of the energy policy of the state and is based on the following principles:

a) To ensure the normal market operation in the field of energy, including the price formation according to competition criteria and to environment protection costs and benefits;
b) To reduce the hurdles to promote energy efficiency and stimulate investments in this way;
c) To promote financing solutions for the initiatives related to energy efficiency;
d) To educate and create the awareness of the users of different forms of energy to reduce the energy consumption by product unit;
e) To ensure the co-operation between the consumers, producers, energy suppliers and public authorities in view of reaching the objectives set in the national policy of efficient use of energy;
f) To support fundamental and applicable research in the field of efficient use of energy;
g) To promote the private initiative and the development of energy services;
h) To co-operate with other countries in the field of energy efficiency and to observe the international conventions of which Romania is a party.

The national policy for the efficient use of energy defines both, the objectives of the efficient use of energy and the ways by which those objectives are reached, especially referring to:

(a) Reducing energy consumption by unit of gross domestic product in Romania;
(b) Increasing energy efficiency in all the sectors of the national economy;

[10] www.eia.doe.gov/erneu/cabs/romaenv.htm
1 BTU (British Thermal Unit) = 1,055 kJ

(c) Refurbishing with new technologies having a high energy efficiency;
(d) Promoting new energy sources;
(e) Reducing the negative impact on environment of energy production, transmission, distribution and consumption in all its forms."[11]

The "law concerning the efficient use of energy" is a step in the right direction, but the realization of the huge potential requires the abolishment of subsidies for fuel, an active policy of dissimination of know-how, the promotion of the advantages of enegergy savings and an effective financing mechanism.

[11] [Romanian Energy Policy association - ROMANIAN ENERGY LEGISLATION: Law concerning the efficient use of energy Article 3]

3 Cleaner energy systems, use of renewable energy

Renewable energy refers to power generated by a renewable source. When the energy is generated, the resource is not depleted or used up. Resources are naturally replenished, and can either be managed so that they last forever, or their supply is so enormous humans can never meaningfully deplete them. Unlike fossil fuels, most renewable energy sources do not release carbon dioxide and other air pollutants as by-products into the atmosphere. As the amount of fossil fuel resources on earth decreases, it is becoming increasingly important to find and utilise alternative fuels.

Renewable resources include:

- wind power;
- solar power;
- biofuels;
- hydro-electric power (HEP);
- geothermal energy;
- tidal power and
- wave energy.

Part of the reason for their limited use is their significant cost relative to fossil fuel or nuclear power generation.

Today´s subsidies and tax policy is in favor of fossil and nuclear power. The investment for the construction of big centralized power stations is also supported by the policy of the international export banks, where it is easier to get credits for one nuclear power plant than to get credits for a variety of small decentralized plants which use renewables as hydro, wind, biomass, solar. However the "fuel" for renewables is clean and pratically free: wind, hydro, solar radiation.

However, as renewable energy technology improves, the cost of these more sustainable forms for energy production become much more competitive.
By an EC funded project it was proved that it is feasible and cheaper to use renewables in remote settlements in the mountain region than to connect them to the national grid.[12]
In principle the government in Romania favors renewable energy equipment (REQ), but due to funds shortages the impact of these sources of energy is extremely small.[13]

[12] Renewables use for rural remote households;Tantareanu C. OPET Romania ENERO
[13] National Trade Data Bank, USDOC, ROMANIA –ENERGY PROFILE

3.1 Contribution of renewables to power production in Romania

Small Hydropower: Romania has a great potential for small hydropower plants. There are about 5.000 favorable locations. Ten years ago there was even an industry producing small turbine/generator sets in Resitaand Caransebes. However, due to the relatively high initial investment needed for such plants, they account for very little in the overall primary energy consumption.

Biomass: Nil for practical purposes although Romania has a very rich soil.

Wind Energy: Nil. There are some experiments.

Photovoltaic Solar Energy: Nil.

Thermal Solar Energy: Some timid experiments, such as getting hot water for industrial and humanitarian purposes, have been done.

Geothermal Energy: Notable potential in some areas, but very little used.

Municipal Solid Waste: There is one project under study for the Bucharest municipality.

A sustainable energy system has to minimise the environmental impact of energy production and use. This requires cleaner energy sources and the reduction of the adverse effects of fossil fuels. The cost and the environmental impact of energy conversion processes will also be tackled, making all systems more efficient and cleaner.

4 Wind power

The utilization of wind energy has a long history in Romania. In the areas Moldova, Dobrogea and in the Danube delta windmills from the end of the 19. century are still in operation. Furthermore still in operation are old water pumps for the irrigation of fields and for cattle watering places, driven by the wind. Some wind power stations were built in high mountain places (up to 2,160 m over the sea level).
The governmental Institute for technical and scientific work developed a wind powered station with vertical axle (type Darrieus) and a cpapcity of 20 kW. Wind power stations of this type operate in different parts of Romania, some of them drive water pumps. Gradually the capacity of the wind power stations designed in Romania was increased. Romanian universities also participated in the development of wind power stations. The technical University of Timisoara already installed a wind power station with three wings in the Banat in 1981 with horizontal axle and a capacity of 300 kW. In 1992 a 300 kW wind power station was built in Sulina, which produces electricity for the national grid. [14]

Romania has a "state program for energy accumulation, recuperation and utilization of renewable and conventional energy sources". Within the framework of this program wind power stations with an installed total capacity of 550 MW are to be built until 2010. In further future the installed total capacity should reach 3000 MW, a capacity which could replace as much electricity as two CANDU 6 units produce.

The average wind velocity at the Romanian coast at the black sea amounts 5 to 7 m/s, on the top of the Carpathians 6-10 m/s, on the plateau Dobrogea and in the southern part of Moldavia about 5.5 m/s.

The average wind speed in Romania in rural areas is about 4,6 m/s[15]. A wind power plant with a capacity of 600 kW at this speed produces annualy 500.000 kWh (0,5 GWh). If the average wind speed is about 9 m/s the energy production will be 2,4 GWh (2 400 000 kWh). The relation of wind speed to energy output is not linear. The energy output increases faster than the wind speed. The duplication of wind speed leads to a fourfold energy production.

The recently opened Alpine wind park in the Austrian Mountains is an impresssive proof of the advantages of using wind energy in mountain aereas.

[14] http://www.igwindkraft.at/zeitung/zeitung16.htm, Windenergie Nr-16 newspaper of IG Windkraft, march 2002
[15] OPET Romania ENERO, Christian Tantareanu "Renewables use for rural remote households"

With a monthly electricity production of more than 4 GWh per month in winter the eleven Vestas V66-plants already produced as much as the annual energy consumption of 3.300 households since their start-up in December 2002. This energy substituted the burning of 1 million litre heating oil or of 2.5 million kilogram of brown coal. 1 kWh electrical energy produced by fossil fuels causes an output of 970 g carbon dioxide. That means that the Tauernwindpark already saved the emission of 9700 tons of CO_2 during its short working period of scarcely two months.

Figure 3: Tauernwindpark in Austria, Vestas V66[16]

Wind Park: technical data:
site: Oberzeiring/Styria/Austria, altitude: 1900m

11 units

Type: Vestas V66 – 1,75 MW (Germany)

capacity 1750 kW (=1,75 MW)

rotor diameter 66m

wind speed:

minimal 4 m/s

average 16 m/s

shutdown 25 m/s

[16] http://www.tauernwind.com/windpark/windpark_tstart.htm

5 Solar power

Solar radiation consists of the radiation that comes directly from the sun as well as the radiation that comes indirectly.
Solar radiation changes with the time of day and year. The solar radiation is also reduced by numerous other factors; even with a clear blue sky, only 90 % of the total solar radiation gets through.

Solar Energy: The potential of the energy delivered by the sun is practically infinite—at least for the next 4 billion years as experts predict. The amount of energy which strikes the surface of the earth in one day exceeds the daily consumption by 10.000 to 15.000 times.

Besides Passive Solar Design, i.e using different methods of construction taking advantage of the sun (Solar Architecture), Solar Radiation can also be actively used: Photovoltaics produce 'clean' electric current ready for use, while a Solar Heating System transforms the radiation into heat.

Passive Solar Design: Buildings themselves, or parts of them, are used as collectors. A typical example is a paned sun room. The glass construction prevents heat loss from the building, hence contributing to a reduction of energy consumption. The air which is heated by the sun can be vented from the sun room and can then be used for space heating.

Through solar building methods a huge amount of heating energy can be saved. Passive solar design (windows facing south, heat insulation, etc.) alone has the potential to save up to 90 % in the cost of heating, while the remaining heat can be produced using solar collectors. Every roof facing south is also a potential solar energy provider. Solar heat collectors and photovoltaic systems can be built into existing roof structures as well as be included in the plans of future building projects. Coordination between architects and solar technology experts is an excellent basis for the highest efficiency and living comfort. Low- or zero-energy buildings face south and combine heat insulation, demand-oriented ventilation, and 'intelligent' solar energy systems. When the energy needed for heating and the CO_2 emissions both decline, then the standard of living will improve.

Solar Power System: Systems used to transform solar radiation into useful energy in the form of heat (solar heating) or electricity (photovoltaics).

The estimated solar irradiation in a typical rural region in Romania varies between 5 – 6 kWh/m² per day during the summer, and 0,6 – 1,2 kWh/m² per day during the winter[17]. All the country has a valuable potential for solar system applications, as the average solar radiation in Romania rages from 1.300 to 1.500 kW/m² per year[18].
The total area in Romania is about 238.391 km². The average solar radiation in Romania rages is about 1400 kWh/m² per year. Thus the solar radiation for

[17] OPET Romania ENERO, Christian Tantareau: „Renewables use for rural remote households”
[18] ESIF – Solar Thermal Strategy – SUN IN ACTION, “The solar thermal market in Romania”

Romania is approximately **330 million GWh per year** (i.e. the theoretical potential for solar energy). Favourable places for the installation of solar collectors for thermal as well as for electrical energy generation are buildings (roofs and fassades) or not used space near settlements (e.g. noise barriers). The technically usable usable building area is approximatly 30 % of the available building area. Thus the available building area in Romania is ca. 630 km², of these ca. 210 km² collector area could be installed.[19]

5.1 Solar Heating

The most important components of a solar heating system are the collector, the water storage tank (heat storage device) and the regulator. Solar heating is the most efficient use of solar energy. Heating collectors convert approx. 25-40 % of the solar radiation into heat.[20] (New efficient heating systems have a conversion factor of up to 85 %)[21]

Every squaremeter collector area in Romania produces about 400 kWh or 1440 MJ thermal energy per year. To replace the total amount of thermal energy for district heating in Romania (62.000 TJ) by means of solar heating 43 km² collector area is required. This are 20 % of the total usable area of 210 km².

Today 100.000 m² (0,1 km²) of collector area in Romania is installed, these are 0,045 % of the usable area. The thermal output of these collectors is 144 TJ[22].

Under the new energy legislation about 2.600.000 square metres of collectors will be installed until 2005 avoiding 1.000.000 tonnes of CO_2 emissions per year[23]. They will produce 1000 GWh thermal energy per year.

The ecological advantages of solar heating systems are: up to 50 % reduction in the demand for conventional heating, and with that less CO_2 emissions – for only small extra costs.

5.2 Photovoltaic

The most important components of a photovoltaic system are the solar cells, which when connected together form a solar module (or solar panel) and the storage battery. If the electricity produced is fed into the grid (grid coupling), then it is done so through the use of an inverter in order to convert the direct current (DC) from the photovoltaic system into the correct voltage and phase of the grid's alternating current (AC)

[19] building area minus space with low solar radiation
[20] http://www.solarserver.de
[21] http://www.sses.ch/de/technik/thermisch.html
[22] ESIF – Solar Thermal Strategy – SUN IN ACTION, “The solar thermal market in Romania”
[23] ESIF – Solar Thermal Strategy – SUN IN ACTION, “The solar thermal market in Romania”

A photovoltaic cell converts 11- 17 % of the solar radiation into electricity.[24] Thus a square meter PV collector in Romania produces between 150 and 240 kWh electrical energy per year. To substitute the 5400 GWh annual electricity produced by a CANDU 6 reactor ≈ 30 km² photovoltaic panels are necessary which is approximately 15 % of the usable area.

[24] http://www.solarserver.de

6 Biomass

Biomass is plant material, either raw or processed. For example:

- Fast-growing trees and grasses, like hybrid poplars or switchgrass,
- Agricultural residues, like corn stover, rice straw, wheat straw, or used vegetable oils,
- Wood waste, such as sawdust and tree prunings, paper trash and yard clippings;

Biomass is stored solar energy that can be converted to electricity or heat.
When biomass is used for the generation of energy, almost no additional carbon dioxide is set free; the carbon dioxide that does get set free through the energetic utilization of biomass is equal to the amount that the plant absorbed from the atmosphere.
Biomass can easily be stored in large amounts. That is what distinguishes it from other renewable energy carriers like solar energy, wind- and water-power.

More than any other energy resource, biomass is capable of simultaneously addressing the nation's energy, environmental, and economic needs.

- Biomass fuels are sustainable. The green plants from which biomass fuels are derived fix carbon dioxide as they grow, so their use does not add to the levels of atmospheric carbon. In addition, using refuse as a fuel avoids polluting landfill disposal.
- Conversion of solid biomass into combustible gas has all the advantages associated with using gaseous and liquid fuels such as clean combustion, compact burning equipment, high thermal efficiency and a good degree of control. In locations, where biomass is already available at reasonable low prices (e.g. rice mills) or in industries using fuel wood, gasifier systems offer definite economic advantages. Biogas production reduces ammonia emissions from liquid manure.
- Biomass gasification technology is also environmen-friendly, because of the firewood savings and reduction in CO_2 emissions. Biomass gasification technology has the potential to replace diesel and other petroleum products in several applications, and thus it reduces imports.
- Biomass can pay a dual role in greenhouse gas mitigation, both as an energy source to substitute fossil fuels (bioenergy) and as a carbon sink.
- Biomass production can often mean the restauration of waste land (e.g. deforested areas) and it is cheap in contrast to the other energy sources.
- Biomass use provides jobs in rural communities and improves the agricultural income situation.
- By using waste as input material waste treatment costs will be reduced. [25]
- Biomass helps saving foreign currencies and increases the regional purchasing power.
- Tolerating of the acre framing flora for the increase of the stability of agrarian ecological systems.

[25] http://rhlx01.rz.fht-esslingen.de/projects/alt_energy/bio/ADVAN.HTML

- Prevention of a eutrophication of proteced areas by thermal use of the growup (composting as alternative is too expensive).
- Biomass can be gained from abandoned farm land and thus increases the recreation value of the landscape.
- Biomass use protects the ground and drinking water by avoidance of pesticides and minimization of nutrient removals by steady planting and prevents erosion.

Bioenergy technologies help protect the environment by making use of renewable plant material such as sawdust, tree trimmings, rice straw, alfalfa and switchgrass; poultry litter and other animal wastes; industrial waste and the paper component of municipal solid waste.
Biological materials are used today in a wide variety of processes, including the production of clean transportation fuels, electricity and chemicals.

6.1 Biogas potential in Romania

Biogas is a renewable energy carrier. Anaerobic digestion is a biological process that produces a gas principally composed of methane (CH4) and carbon dioxide (CO_2) otherwise known as biogas. Its main component, methane, makes up 40 to 80 % of the total volume is usable for the generation of energy.
These gases are produced from organic wastes such as livestock manure, food processing waste, etc.
Agricultural biogas plants use the excrements of their animal stock. Organic material with a high water content is the most suitable. Biogas is produced in a septic tank in a microbial process and is energetically utilizable after temporary storage. The usage of biogas is especially effective in decentralized block-type engine heating stations. Biogas can also be produced in the agricultural industry and communal disposal industry. However, in these areas, waste management is to be put before the production of energy.

Anaerobic processes could either occur naturally or in a controlled environment such as a biogas plant. Organic waste such as livestock manure and various types of bacteria are put in an airtight container called digester so the process could occur.

Basic conditions to guarantee economic succes of a biogas plant are:

- Minimum livestock: 60-100 LSU (livestockunit)
- High utilization options on location
- Economic utilization of the motor rejected heat all over the year
- long standing availability of material
- sufficient subsidies for investment

The investment costs for a 100 LSU-plant in Austria are about 150 000 Euro.
Such a plant with the average daily gas production of 150 m^3 can produce 800 kWh fuel energy and 200 kWh electric power.

Animal excrements from agriculture are the most important input for agricultural biogas plants. The following table is an overview about the biogas potential in Romania.

Table 3: Livestock breeding intensity in Romania 2000

number of livestock animals in Romania		specific conversion factor	livestock units
cattle	2.870.000	0,7	2.009.000
cows	1.649.000	1,2	1.978.800
pigs	4.797.000	0,135	647.595
sows	323.000	0,425	137.275
sheep	7.657.000	0,075	574.275
goats	538.000	0,075	40.350
poultry	83.000.000	0,0034	282.200
Total			5.669.495

Animal excrements from agriculture in Romania based on 5,7 million livestock units have a caloric value of 62,5 PJ. Biogas can be used as a fuel for combined cycle systems to generate electricity and heat water. These systems have a high efficiency.

Total efficiency of biogas systems in Germany and Austria

Table 4: An exemplary module program for sewage treatment gas/bio-gas operation (SCHMITT ENERTEC GmBH, company in germany for combined cycle systems, combustion engine units, motor engineering, plant construction , URL: http://www.schmitt-enertec.com/)

modultype	electrical output	thermal output	energy use	total efficiency
	kW	kW	kW	%
FSB-65-KSM	53	82	158	85,4
FSB-125-KSM	101	174	312	88,1
FSB-360-KSM	297	475	869	88,8
FSB-710-KSM	578	769	1616	83,4
FSB-950-KSM	771	996	2130	82,9
FSB-1125-KSM	910	1131	2430	84

In the Austrian town Guessing is a regional center for research and development in the field of utilization of biomass for sustainable energy production. A new type of small power stations was developed here. As a central step a gasification procedure is used, which offers clear advantages by using it as a combined heat and power station. The simultaneous supply of heat (for district heating and process steam) and electricity guarantees a high fuel exploitation (see diagramm). Thus for example

2 MW electricity and 4.5 MW district heat are made available in Guessing by the utilization of 1.760 kg wood per hour, which corresponds to an entire fuel use of over 80 %. [26]

With such new and very efficient technology biogas plants will be competitive to conventional power stations:

[26] http://www.waste.at/data/ins06_2002_5.cfm

"The use of abandoned agricultural area of 1 million hectar for the production of energy plants for the biogasification could replace two atomic power plants with a capacity of 1.000 MW each," said Josef Plank of the Styrian chamber for agriculture. *"These new plants for the utilization of biogas represent a capacity of 6 billions kW electricity and 6 billion kW of warmth."*[27]

In order to replace the electricity produced by one CANDU 6 unit several small combined cycle biogas plants are necessary (e.g. 35 of the above described type). In order to supply the demanded amount of energy plants for the gasification 3500 km² farmland are needed, which is less than 2 % of the total area of Romania or about 30 % of today's arable area. During the integration process of the Romanian economy in the EC market, agrarian production will become more and more intensive and part of the farmland will become available for new processes. Energy plant generation is a new opportunity for these regions and its inhabitants.

6.2 Biomass from forest and agriculture

Biomass[28] material from forest and farmland is firewood, woodshaving, sawdust, bark, pellets, waste of paper and pulp production, straw, organic fuels, energy crops, waste and sludge.

Waste products from agriculture are an important input for agricultural biomass plants. The following table contains different agrarian structures and their energy output in Romania.

Table 5: Different agrarian structures and their energy output in Romania

Romania				
agrarian structure	Mio ha	harvest amount per year MWh/ha	TWh/a	PJ/a
arable	9,4	40	375,2	1350,9
hayfields	1,5	35	52,7	189,9
pastures	3,4	20	68,8	247,8
forest	6,5	16	103,3	371,9
TOTAL			600,1	2160,5

Wood is available in large amounts in Romania.
There are several methods to prepare wood for energy generation:

- Producing billet wood requires working with saws and axes, which is labour-intensive and results in high costs.
- Sawing residue is the left-overs from wood-processing industrial companies. It consists of large bulk as well as of smaller material (e.g. saw dust). The bulk material is processed to wood chip.
- The wood used is usually residue from forest conservation measures, which cannot be used for other purposes, but should not be left in the forests because it diminishes the growth and health of better trees. This kind of wood is an energy carrier that is ready without further processing; if it were

[27] http://www.oe-journal.at/Aktuelles/0901/wutearchiv25090110.htm
[28] http://www.biomasseverband.at

not put to use, it would simply decompose. Increased exploitation of this wood for energetic purposes has no negative effects on the strict law of sustainability which is employed in forestry.
- If energy prices rise, energy wood plantations with fast-growing tree populations like poplar and willow might be a realistic option.

In practice only a small fraction of the theoretical increase of wood in forests is usable for energetic purpose. Topografic formation e.g steep slopes and protection forests limit the utilization possibilities in multiple regard.

Wood grows with the strength of the sun directly in Europe. The drying process of the energy wood is made by the solar power. The energetically expenditure for cutting up (cutting, splitting) amounts usually less than 1 % of the energy contained in the wood. 1 kg dry wood has a heat value of 5 kWh. In air-dry condition with a water content of approximately 15% the heat value is about 4,5 kWh/kg. Modern wood firings show less emissions and high efficiency (up to 95 %).

7 Hydroelectric Power

7.1 Advantages and disadvantages of hydroelectric power[29]

Hydroelectric power plants have many positive and negative environmental impacts, some of which are just beginning to be understood. These impacts, however, must be weighed against the environmental impacts of alternative sources of electricity. Until recently there was an almost universal belief that hydro power was a clean and environmentally safe method of producing electricity. Hydro-electric power plants don´t emit any of the standard atmospheric pollutants such as carbon dioxide or sulfur dioxide given off by fossil fuel fired power plants. In this respect, hydro power is better than burning coal, oil or natural gas to produce electricity, as it does not contribute to global warming or acid rain. Similarly, hydro-electric power plants do not result in the risks of radioactive contamination associated with nuclear power plants. Hydropower does not consume natural resources. It is a simple and proven technology with a high efficiency (about 90%). Although the investment cost are high (500-3000 Euro/kW installed capacity), the plant has a very long lifetime and the operating costs are small (cheap maintenance and operation).
Moreover you gain indirect advantages due to multi-purpose use (irrigation, navigation, flood protection, potable water supply, recovery, pisciculture).
Nontheless hydro power can cause heavy impacts to the environment by disturbance of the boulders and water balance, overflowing of otherwise usable surfaces and ecologically valuable habitats, interruption and restriction of the habitat for migratory fish, and unfavorable social effects by the evacuation of people (big dams).

7.2 Opportunities for Romania[30]

With its many rivers, Romania has great potential for hydroelectric power (as much as 14,800 MW). The total hydroelectric power potential is about 40 TWh per year of which 12 TWh per year have already been developed. There may be as many as 5,000 locations in Romania that are favorable for small hydroelectric power plants. Many states define small hydroelectric power plants as facilities with a capacity less than 30 MW.

The Romanian government has encouraged foreign investment in hydropower through Hydroelectrica, the state-owned hydropower producer. In 1999, Sulzer Hydro of Switzerland won a $154 million contract from Hydroelectrica to refurbish six turbines at the Portile de Fier I (Iron Gates I) power plant on the Danube River. There are twelve turbines at the Iron Gates plant; six are operated by Romania and six are operated by Serbia. It is expected that the project will be completed in 2005 and the capacity of the six Romanian turbines will increase to 1,290 MW from their present capacity of 1,070 MW.

[29] http://www.iclei.org/efacts/hydroele.htm
[30] http://www.fe.doe.gov/international/romnover.html

In addition to Portile de Fier, there are eleven other hydroelectric facilities with capacities of at least 100 MW, and dozens of medium-sized facilities of at least 30 MW. Collectively, these power stations represent about 77% of Romania's currently-operating hydroelectric generating capacity.
In addition to these larger hydroelectric facilities, there are also many smaller power stations. The Raul Mare River has a series of 10 hydroelectric power plants, each between 10 and 15 MW. Similarly, the Strei River has a series of seven small hydroelectric power plants, each less than 10 MW.

The yet planned projects achieve an increase of capacity of 200 MW alone by refurbishment of one big hydro power plant; This shows that the technical improvement of the existing 640 hydro power plants in Romania could increase the available capacity substantially.

Even if it is not sustainable to develop the total potential of hydro power, an ecologically sound development of a part of the 5000 favorable sites could be discussed.