Favorable Energy Management to Extend the Use of Solar Energy in Romania

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Abstract

Solar energy can be used in large areas in Romania, particularly in regions of south, south-east and south-west of the country. Taking into account the weather-solar conditions in Romania, the use of this form of energy is cost-efficient for both domestic heating, or for obtaining domestic hot water.

The solar receptors run within time interval from March to October, with good yield and requiring relatively reduced investment. It is also expected the obtaining of electrical energy from the solar photovoltaic stations, but in this case investments will be much larger. Granting of green certificates, as legal rights for investors and/or of subsidies, facilitates both Romanian and foreign investments in this energetic field. Thus, Romania will be fitted over the next few years in the European Union directives for the reduction of greenhouse gas emissions.

Keywords: *electrical energy production, solar energy, thermosolar energy, photovoltaic effect, solar panels, energy management*.

JEL classification: O13, P48

Introduction

Energy management means to minimize energy costs and environmental impact without affecting production and quality by the achievement of continuous improvement of energy performance, energy efficiency and energy conservation (Abdelaziz, Saidur, Mekhilef, 2011). This paper aims to discuss some general aspects of solar energy conversion ways and introduction of solar energy stations in Romania.

The sun might emit energy for another 5 billion years, representing therefore an inexhaustible source of energy. Solar energy is expected to be the foundation of a sustainable energy economy, because sunlight is the most abundant renewable energy resource. It is estimated that the sun emits in outer space a huge amount of energy ($22{,}252 \times 10^{27}$ J/min) (Visan, Angelescu, 2002). From this, only few part of solar energy emitted reaches the Earth, due to the small angle for the trajectory of sun radiation towards our planet. However, three days of the solar

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radiation are equivalent to the energy production delivered from 1.75 mil. nuclear reactors, each of 1000 MW power, or about 20000 times the currently consumption of energy in the worldwide. According some authors (Leca, Musatescu, 2008) the total solar energy emitted toward the earth in an hour can cover energy needs on a whole year.

The availability of this energy depends on the day-night alternation, latitude, season and cloud amount on the sky. Depending on the geographical position, solar radiation has different intensity, the largest annual values about 800 kJ/(cm^2. year) being along with wide desert area, where the cloud amount is very low.

The use of solar energy offers a number of advantages, as a resource inexhaustible, clean and available virtually stretched out on very large areas across the globe. However, the extensive recovery of solar energy is experiencing some difficulties, owing to intermittent cloud amount (due to changing season and day/night alternation), oscillation in solar intensity, difficulties in capturing and storing solar energy. Solar energy is diffuse and not permanent, which in turn needs a capture of this form of energy on large surfaces. Also, it requires the concentration of energy captured on some focuses, the achievement of effective means for the storage of this energy, eventually with a combined use with other types of power stations.

In the terrestrial regions with constant solar density and lighting, where the absorption of caloric energy may reach up to 40%, the available solar energy to the ground can be used economically for production of electricity together with the air conditioning of houses, domestic water heating, desalting of sea water or other surface waters, the obtaining hydrogen or ammonia, or also for carrying out some metallurgical processes. In addition to applications in outer space, it has been demonstrated during near future the ability to use this form of energy on road signs, propulsion of plains, trains and cars, as well as in mobile telephony. The main issue with using solar energy is that it has not yet been made efficient enough to be a viable source for energy. Finding a viable design that utilizes solar energy as the main source of energy will indeed have immense benefits for many countries (Atieh, and Al Shariff, 2013).

The valorisation of solar energy can be achieved by its conversion either into thermal energy (of low- or high-temperature), or directly into electricity through photovoltaic effects which may be also photoemisive, photogalvanic or photomagnetic effects. Since 2010 year, photovoltaic solar power stations have produced electricity in more than 100 countries. In this respect, India holds since the year 2012 the largest solar photovoltaic cell type in the world, that can provide 605 MW, which is sufficient to power a city of average size (http://www.descopera.ro/dnews/9567818-india-a-inaugurat-cea-mai-mare-centrala-solara-din-lume). The biggest solar energy station in Europe is located in Spain, at Salamanca. This power station with 13.8 MW capacity has solar panels covering more than 36 hectares and is used to ensure the demand of 5,000 houses. As an economical consequence, 27,930 barrels of oil are saved per year and carbon dioxide emissions are significantly reduced (http://www.ecomagazin.ro/cea-mai-mare-centrala-de-energie-solara/). An important position in Europe in the field of solar energy conversion is occupied by Germany where one of solar power station has 12 MW capacity.

The energy problem with in the next years is not only increased energy efficiency or new procedures of using efficiently the existing carbon based fuels, but also the use of renewable energies. In this respect, the solar energy is to be a major primary energy source, utilization requiring solar capture, conversion and storage (Lewis and Nocera, 2003; Armaroli and Balzani, 2006). It is worth to mention that Jack Steinberger, who gained Nobel Prize for physics in 1988, (http://www.windaction.org/news/21371) stated that the emplyment of solar thermal energy is much more efficient than the wind, geothermal and that produced by the marine waves.

1. Thermal energy obtained from solar energy

Solar collectors and their applications in existing solar thermal systems are a hot topic all over the world. Numerous papers have made a comparison of performance and cost effectiveness of solar water heaters at different collector tracking modes (Michaelides *et al*., 1999; Cristofari *et al.*, 2003; Kalogirou 2004; Karsli 2007; Sözen, Menlik and Ünvar, 2008; Andersen and Furbo, 2009; Zambolin and Del Col, 2010; Hayek, Assaf and Lteif, 2011; Ma *et al*., 2011). Capturing radiant solar energy is carried out with receptors, with solar cells, or heliothermic converters, which work with or without concentrating solar radiation. (Visan and Angelescu, 2002). Below there are described the main types of solar receptors.

Receptors without concentrating solar radiation using both direct and diffuse sunlight, the surface area of the absorption being identical to the surface that intercepts solar radiation These devices do not require precise orientation toward the sun, have a simple construction and relatively easy maintenance. Regarding the shape of the area acquiring they can be plane, cylindrical and semi-cylindrical.

The working domain of *receptors with solar cells* ranges the low temperatures, of about 100^0C (above the ambient temperature); they are used in the heating and air conditioning system installations of buildings, domestic water heating, facilities for drying, distillation of water etc.

Receptors with concentration of radiation (focus of solar radiation) may be fixed and mobile. Depending on the operating principle and construction of concentrator, the density of the radiation flux acquiring on the surfaces of the recipient can vary from low values of 1.5 -2.5 kW/m^2 to very large values, of approximately 10000 kW/m^2. As with the increase in density of the radiation flow, the temperature at which heat is acquired useful (1970-3000^0C) increases too. In order to obtain thermal energy in these very high temperatures (2000-3000^0C), the solar rays must be concentrated on reduced areas (and even a point) by use the rearparabolic mirrors as a hub (USA, France, Japan, etc.). The concentrator can be positioned automatically towards sun. The parabolic mirrors with central receiver and mechanism rotating on the sun have around 80% conversion efficiency in comparison to 50% efficiency for linear focalisation or 30% efficiency for plane collectors. Systems with focalisation of sun radiation are applied to modular facilities, which may be placed either in a industrial complex plant (as integrated), or to generate electricity in isolated locations or those with reduced power generation networks.

In a *sun tower* system as solar central receiver, the solar rays are focused by a series of numerous mirrors, forming a large reflective surface. Thus, the solar radiation reflected from mirrors is focused on solar tower of reception, which is located at a height of 260 m, in the middle of the field of mirrors. A plant with such solar tower having a heliostat field of 1.3km^2 area (located in Barstow desert, California) provides a power of 10 MW, at a cost of 500-1000 dollars/kW and can be used as of-the-art energy source un tower systems are also promising for using in installations of the chemical industry, for instance in the production of ammonia, gas of synthesis or hydrogen evolved from water electrolysis etc.

Solar panels for heating water are also other examples of commonly-used solar receptors, which convert solar energy into thermal energy (http://panourisolare.net/). During harvesting solar energy, solar panels can convert more energy when sunlight is perpendicular to the panel; once the sun's light begins to hit the panel with an angle, they become less efficient, so fixed solar panels are only efficient at noon (Roth, Georgiev and Boudinov, 2004). Usual constructive types of thermal solar panels may be: (a) non-pressurized; (b) pressurized; (c) separately pressurized.

a) *Non-pressurized solar panels* **-** solar panels are named the summer solar panels, and they cover the greater part of the needed daily domestic hot water during the period from March to October. They are really easy to install and require no additional costs of maintenance. The operating time is about 25 years. Their vacuum tubes receive solar radiation and convert it into heat, thus warming water in the inner tubes.

b) *Pressurized solar panels* operate throughout the year and can absorb heat even on the cloudy days; also, they work at very low temperatures of the environment. During their operation, the vacuum tubes receive solar radiation and converts it into heat, which is used in the heat exchangers located in the upper part. The heat transported by the liquid located inside the tank surrended the copper manifold, which in turn transfers to water which flows inside. The heat losses in solar panels with vacuum tubes are practically non-existent.

c) *Separately pressurized solar panels* may not operate independently, but must be connected to a boiler located in the area of consumption (in the building). Solar energy is captured by vacuum tube, where it is transferred to copper heat-pipe. In the top of this pipe the heat is transferred to the heater agent (ethylene glycol) which transports it to an exchanger; finally the hot water from boiler is used as domestic hot water or heating agent.

In general, the solar panels for heating water have multiple advantages for users and for the environment: (i) they work regardless of the external temperature (even and temperature around -20^{0}C), or in cloudy days, having energy efficiency and zero-cost for conventional fuels for at least 5 months per year; (ii) they work even if one or more tubes are broken; (iii) the damaged tubes may be easily changed and (iv) the delivered thermal energy is environmentally-friendly, because there is no environment pollution.

2. Direct conversion of solar energy into electricity

The conversion of solar energy into electricity from photovoltaic effect uses semiconductor materials. The sun radiation is oriented to “n-p” jonctions for obtaining directly electrical energy (Genwa and Sagar, 2013). Solar cells made of small plates of semiconductor material generate a low voltage (about 0.5V) and, therefore, they are connected in series, or in parallel. A system of solar cells is guaranteed for 10 - 24 years of operation, with a relatively low conversion efficiency, usually in the range of 10–20% for commercially available silicon cells and up to 39% for more sophisticated multi-junction cells. In practice, the photovoltaic panels produce direct current (*dc* current) with variable parameters in time, that make them inadequate for charging of batteries. For this reason, a complete photovoltaic system contains in addition, classical batteries, charging regulators and inverters for converting *dc* current into alternating current (*ac* current).

a) *Solar power centrals* (named also *solar parks*) are connected to an electricity network and are installed on the field open, with photovoltaic panels installed on metallic stands that may be fixed or rotary, in order to orient automatically towards the sun. Such a central produces approximately 30% more than just consuming it, but requires more maintenance costs and therefore is more expensive. The solar installations can be mounted on the ground, or can be integrated on the roof or walls of a building (Building Integrated Photovoltaic, BIPV). Due to growing demand for renewable energy, the manufacture of photovoltaic solar cells has developed considerably in recent years, scientific research focusing on new semiconductor materials and technical designs more and more effective.

b) *Solar photovoltaic cells for the use of a family or few persons* are intended for their own consumption, the extra energy being delivered to the main electrical network. Photovoltaic panels are installed on the roof of the building, producing 2-10kW. These cells represent a perfect solution for countries in Asia and Africa, in which the main electrical network (national network) is undevelopped; for instance, they are appropriate for remote (or solitary) buildings, being sometimes supported with classical batteries and generators.

c) *Sunlight centrals attached to units of production* have a support from electrical network and, when it is produced an excess of energy, this is delivered to the network. If the factory is far from network, the solar photovoltaic central is supported with a generator.

Modern photovoltaic (PV) solar cells or concentrating photovoltaic (CPV) solar cells are provided with tracking systems that can modify the panels' position so as to face always the sun directly (Rubio et al., 2007). Because of their ability to constantly face the sun, these solar cells having a tracking system are 40% more efficient than a fixed, single axis solar system and can nearly double the energy output. A way to achieve a better efficiency in photovoltaic operation is cogeneration, that means photovoltaic effect together a capturing the waste heat and using this heat as an additional energy product. The cogeneration can be achieved with hybrid photovoltaic/thermal collectors that contain a heat exchanger behind the photovoltaic cells; the heat exchanger collects the heat rejected from the cells and sents it to consumer (Van Helden et al. 2004; Hasan and Sumathy, 2010; Chow, 2010).

3. The potential use of solar energy in Romania

In the case of Romania, the total annual radiation is about 400 kJ/(cm^2.year), but it can differ on the relief; thus, the sunlight energy is approximately 950 kWh/m^2/year in the mountain areas, 1300 kWh/m^2/year in the areas of hills and plateaus and over 1350 kWh/m^2/year on the plains. A map representing the solar energy potential distributted over the territory of Romania is shown in Figure 1.

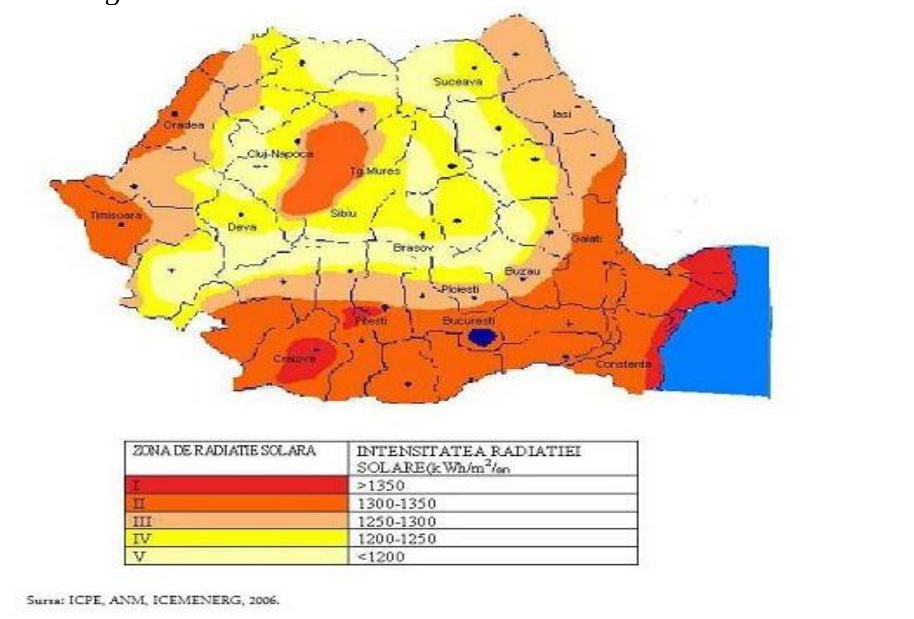

Figure 1. The map that indicates the solar energy potential in different zones in Romania

In Romania, the investments regarding solar systems have been made in particular in domestic areas located in the Apuseni Mountains, Dobrogea and Danube Delta, as well as in radio telecommunication stations and installations of water pumping. Romania has a huge potential for the production solar energy (ICEMENERG). According to the national energy strategy of Romania, the overall solar energy potential of the country can generate annually 1.2 TWh of electricity, representing 2.5% of national consumption today.

Surfaces with the greatest solar energy potential are located in Dobrogea, in a large part of Romanian Plain and in the western regions of the country. Calculations indicate that a maximum valorisation of solar potential in our country can substitute costs required for approximately 50% of the volume of domestic hot water, or 15% of the heat energy for domestic heating of building.

Among environmental-friendly and renewable energy sources, the solar energy is remarked by using simple installations and working temperatures around 100°C, therefore it does not require high costs. This is why solar energy conversion is particularly attractive for heating of building and preparation of domestic hot water. In weather-solar conditions existing in Romania, a solar-thermal receptor operates between March and October, with an output efficiency of 40% - 90%, in spite of some problems caused by the fluctuation and intermittence of sunlight.

The relief of our country is an appropriate area for the use of thermo-solar panels and that is why the investment in solar energy should have a guaranteed profit. European Union has built up and launched several Programs within the context of Solar Heating and to enhance the performances of solar photovoltaics. The support for these projects from the European Union is powerful, evidence being the turnover of 600 million euro allocated for energy in the FP 7 Program (2007-2013).

Converting solar energy into electrical energy is still expensive. The costs for a photovoltaic device to capture solar energy are approximately 5-10 euro/watt installed power. Reducing these costs involves technological and economic measures, as the followings: reduction the cost of semiconductor material; increase the efficiency of photovoltaic conversion of solar energy; achievement of mixed system with both photovoltaic and thermodynamic operation for the recovery the waste heat resulted as unconverted solar energy into electrical energy, etc. Despite the advance in the development of solar cells material, design and equipment, the commercialisation of photovoltaic cells (as well as of thermal solar panels) is still limited. This limitation is due mainly to the high cost materials and the failure to target the mass market.

In the case of Romania, the energy produced by solar-photovoltaic procedures is supported by regulations, as Law No 134/2012 concerning the promoting system for energy production using renewable energy sources. In order to promote the production of such energy the government affords to electricity producers that use renewable energy sources four green certificates for each MWh delivered within national electrical network. A *green certificate* is a document that confirms the production of 1 MWh electricity from renewable sources and can be sold on the market for green certificates, in a separately domain relative to electric power,. The price of the green certificates varies between limits established by a Governmental Decision, the minimum price being imposed for the protection to producers, and the maximum price required for protection of consumers. Starting with the year 2009 the price is regulated, by the law, to a value between 27 and 55 Euro for trading on the market of bilateral contracts regarding green certificates. The number of green certificates is given to energy producers depending on the nature of renewable energy source. As an example, the energy generated from biomass and biogas will get three green certificates per MWh, plus a certificate for increased efficiency. As in all the countries where the solar energy is valorised, in Romania the price for a unit of electrical energy produced by conversion solar energy is quite high and the most parts of costs are still supported by consumers.

If solar energy production should not be subsidized by the government, the producers would be unable to resist competition in most markets, because the repayment time is still too long. In this context, the forecasts for solar energy market are not divulged, owing to the existent crisis of governmental budgets and competing interests. In Europe, only in Spain it has been decided the reduction of grants (http://www.ecomagazin.ro/pretul-real-al-energiei-solare/, because this country is the largest user of solar energy in the world due to its energy production of 2.5 GW (much more than the objective of Spanish government).

4. The state of investments in Romania for the use of solar energy

Due to advantages of domestic water heating and warming the buildings by conversion of solar energy, an increased interest for this field is in recent years in Romania. Several international companies and also Romanian thermo- and hydroelectric companies are already studying the fabrication of such thermal systems which are addressed especially to individual consumers. The investments for thermal solar panels are recovering in 3-4 years and, as consequence, the other remaining 20-22 years of operation represent a saving of either fossil fuels or electricity. Table 1 shows the foreseen values of investments in Romania for thermal solar panels.

Table 1. The investment characteristics in the case of solar panels implementation

Production unit	Investment value, Euro	Repayment time, years	Total operating time duration, years
(Hot water + thermal energy for domestic heating)/building unit	within range from 500 Euro to few thousand Euro	3-4	20-25

Another main direction of solar energy conversion, *i.e.* implementation of photovoltaic power centrals, is also a study object for the same big companies from Romania and from abroad. The junction of a photovoltaic plant to the main distribution network of electricity imposes some requirements on the technical reasons (voltage, frequency in allowable limits) and also on the environment protection. The benefits for the environment are important: do not pollute atmosphere, surface water and underground water, soil and subsoil; shall not be used toxic and dangerous substances; urban villages and the objectives of public interest will not be affected much more than in the current system of distribution of electricity. Companies already have sufficient lands on which the photovoltaic centrals may be placed together with technical systems of connection to the national electrical network. It is estimated a period of 2-7 years for the depreciation return on investment (repayment). Certainly, to the investment costs for the photovoltaic plants the expenditures for the connection to the electricity network should be added. An example of the distribution of the costs for construction of a photovoltaic plant is presented in Table 2.

Table 2. The share of the expenses necessary for implementation of a photovoltaic plant

Chapter of expenditure	Subsection of expenditure	Percentage
1. Charges for obtaining and upgrading the field of construction	• Obtaining the land; • Field upgrading; • Facilities for the environmental protection	~ 1%
2. Charges for design and technical support	• Study of the amplacement; • Fees for opinions, agreements, and authorization; • Design and engineering; • Advice; • Technical assistance	~ 16%
3. Charges for the basic investment	• Construction of structures and facilities; • Assembling technological equipment	~ 73%
4. Other expenses	• Organization of the building site; • Commissions, rates, taxes, the cost of credit; • Incidental and unforeseen expenses	~ 10%

In the case of photovoltaic power stations, the profitability depends, as usually, on costs, incomes and operational expenses. The gross rate may reach up to 12-21% per year. The total costs of implementation are, of course, included in the unitary cost of energy delivered and they can reach 1.3 to 2.1 Euro/Watt. Numerous factors influence this cost value: quality of the equipment installed, technical solution chosen, nature, shape and type of terrain, distance from a line belonging to main electricity network, position of location field towards cardinal points, costs of connection to the national energy system, etc. The execution of such investment lasts between 2 and 6 months, depending on the type and location terrain and weather conditions.

Obviously, the revenues of a photovoltaic station come from the sale of delivered electricity and the transferability of the green certificates on the stock exchange. The operating expenses may reach a percentage of 3-10% of annual income and comprise: security, maintenance of equipment and terrain, system monitoring, etc.

We take, as an example, an investment of 3-4 million euro/MW for a photovoltaic plant that can produce electricity for the price of 380 Eur/MWH (Nicholl, D., http:// www. adevarul. ro/financiar / Cine_investeste_ in_energia_ solara_ din_ Romania _0_363564035.html). For a capacity of 5000MW/year and a price of 0,25 Euro/kW for delivery electricity in the network, a revenue of 1.25 million Eur/year can be feasible achieved; the calculated depreciation period is 9 years. If the incomes are supplementary increased by receiving money for 4 green certificates (each having a value of 55 Eur/MW), a sum of 1.122 million Eur/year will be collected in addition, this leading to a new depreciation period which may be shortened even at approximately 5 years. For an estimated operating period of 25 years, difference up to 25 years (i.e. ~20 years) takes a substantial profit to investors.

Romania should take into account the recommendation of European Commission to increase gradually the percentage of green energy consumption reaching in the year 2020 to 38%, from which approximately 24% will be provided from renewable sources: wind, solar and biomass. At that time, in accordance with National Plan of Action in the Field of Energy from Renewable Sources (PNAERS), in our country must be produced 4,000 MW from wind power sector, 260 MW from solar energy and 600 MW from biomass (see Table 3).

Table 3. Developments in energy generation plants from renewable sources

Year	Investment, billion Eur	Weighted from total energy costs, %	The energy source		
			Wind	Solar	Biomass
			Installed power, MW		
2012	3	19	1822	49	40
2020 (estimated)	> 4,5	24	4000	260	600

In this year, taking into account the present cost of technologies, the estimations have foreseen over 4.5 billion Eur for investments in the three energy fields.

Table 4. Objectives of Romania by each step, to increase percentage of renewable sources of energy

Year	2014	2016	2018	2020
Weighted from total energy costs, %	19.66	20.59	21.83	24.00

Moreover, European Commission established even intermediate values of investments in years, in order to support Romania to reach the final proposed target in the year 2020 (Table 4).

Conclusions

Conversion of solar energy is very attractive procedure in Romania for both heating and electricity production, together with the other two renewable energy sources: eolian energy and biomass. Although Romania is a newcomer on the renewable energy market, the development of investments in this field has been rapid, especially due to European Union policies to reduce emissions of greenhouse gases. Solar energy is one of environmentally friendly, non-polluting and renewable energy sources. It has a huge potential to be used for obtaining thermal energy, necessary in hot water preparation and heating the dwellings. Also, a target is to obtain directly electrical energy, in particular through photovoltaic effect. Whatever kind of energy is produced, this is addressed both to domestic and industrial consumption.

The use for the purposes of obtaining domestic hot water or heating the dwellings has already entered on the Romanian market, due to reduced costs of investments in this thermal conversion procedure. Moreover, parks with solar panelsthat produced electricity have begun to appear across the landscape in Dobrogea, Timis or Romanian Plain, which are areas with high potential solar radiation. However, few of them are now connected to the main electricity networks. In this respect, the efforts for investments are still high, because of costs for solar panels, additional equipment to bring electric current, voltage and frequency to national energy network requirements, as well as costs for distribution.

Granted, in accordance with the legislation in force, of four green certificates for each one MW produced and distributed in the network is of interest to both Romanian and foreign investors in photovoltaic solar energy conversion.

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