

# Aspects of primary production of solar thermal and photovoltaic energy in European Union

Marian Zaharia<sup>1</sup>, Aniela Bălăcescu<sup>2</sup>, Aurelia Pătrașcu<sup>3</sup>

<sup>1</sup>Petroleum-Gas University of Ploiești, [marianzaharia53@gmail.com](mailto:marianzaharia53@gmail.com), Romania

<sup>2</sup>“Constantin Brâncuși” University of Târgu Jiu, [anielabalacescu@yahoo.com](mailto:anielabalacescu@yahoo.com), Romania

<sup>3</sup>Petroleum-Gas University of Ploiești, [patrascuaura@yahoo.com](mailto:patrascuaura@yahoo.com), Romania

**Abstract.** The green energy production is an imperative of the sustainable development. In this context, the energy production based on solar radiation is an important alternative. Taking into account these aspects, the paper analyses the evolutions of primary productions of solar thermal and solar photovoltaic energy between 2000 and 2015 both in absolute values and in per capita values. The results of the analyses emphasize the exponential development of the productions of these types of energy. They also highlight the existence and even the emphasizing of the Europe Union productions concentration in some states like Spain and Germany that have produced 73.96% of the primary production of solar thermal energy in 2015, respectively Germany and Italy that have produced 62.2% of the primary production of solar photovoltaic energy, in the same year.

## 1 Introduction

Although in the last decade of the last century the primary renewable energy production has had a general growth trend that, in relative values, have surpassed the primary energy production from classical sources, the real boom of renewable energy production has occurred after 2000. Thus, if in 2000 the primary renewable energy production has represented 11.06% of the total primary energy production, in 2005 it has reached to 14.13% and in 2015 to 28.34%.

The sun has been used as a source of thermal energy since ancient times. However, the thermal energy production was only 149.1 Thousand tonnes of oil equivalent (TOE) at European Union (28 countries) level (EU-28), in 1990, representing less than 0.02% of total primary energy production.

The photovoltaic energy was practically inexistent in 1990, its primary production volume being of only 1.1 TOE. However, it has recorded an explosive growth since 2000. These aspects are the results of the significance given to the renewable energy production at EU level, K. Traube [1], H. Lund [2], J. Andrei, J. Subic, and D. Dusmanescu [3], as well as of the imperatives of sustainable development, A. G. Simionescu, M. C. Dragomir [4], A. L. Dumitrescu [5], J. V. Andrei, R. A. Ion, G. H. Popescu, E. Nica, and M. Zaharia [6].

Starting from this aspect, as well as from the 28 / European Commission Directive 2009/28 [7] and from

the European Commission Communication 572/2015 [8] regarding the renewable energy in the EU-28, the paper emphasizes, on the one hand, the evolution that the primary production of solar thermal and solar photovoltaic energy has recorded during 2000 and 2015 and, on the other hand, highlights the place occupied by the EU-28 member states both in the total energy production based on solar radiation and in per capita production of solar thermal and solar photovoltaic energy.

## 2 Methodology

The analysis of the evolution of the primary productions of solar thermal and solar photovoltaic energy in the EU-28 is based on the statistical data series [9] regarding the two sources of renewable energy that form the two matrices of this type:

$$X = \left\{ x_{i,j} \right\}_{i=1,\overline{n},j=1,\overline{m}} \quad (1)$$

In relation (1), the variable  $n=28$  that corresponds to EU-28 member states and variable  $m=4$  that corresponds to data series from 2000, 2005, 2010 and 2015.

In the first part of the analysis, the significance of the primary productions means of solar thermal and solar photovoltaic energy that have been calculated at EU-28

\* Corresponding author: [marianzaharia53@gmail.com](mailto:marianzaharia53@gmail.com)

level for those 8 data series has been tested. The tested hypotheses were:

$H_0$ : the mean value is not statistically significant (the mean does not significantly differ by zero).

$H_1$ : the mean value is statistically significant (the mean significantly differs by zero).

In order to test them, the bilateral *t test* (*Student*) has been used. The statistics of the test ( $t_c$ ) for the data series corresponding to year  $k$  is:

$$t_c = \frac{\bar{x}_k}{\frac{s}{\sqrt{n}}}, \quad s = \sqrt{\frac{\sum_{i=1}^n (x_{i,k} - \bar{x}_k)^2}{n-1}} \quad (2)$$

The condition of accepting the null hypothesis ( $H_0$ ) is:

$$t_c \in \left[ -t_{\frac{\alpha}{2}, n-1}, t_{\frac{\alpha}{2}, n-1} \right] \quad (3)$$

where  $t_{\frac{\alpha}{2}, n-1}$  is the critical value of *t test* (2 - tailed) for a

significance threshold  $\alpha$ . In particular, in the analyses that have been carried out  $n$  is equal to 28.

To test the statistical hypotheses, the 95% Confidence level (significance threshold  $\alpha=0.05$ ), has been chosen. The unit of measure used for primary production of solar thermal and solar photovoltaic energy is thousand tonnes of oil equivalent (TOE).

### 3 Results and discussions

The achieved analyses and the presented results refer both to the primary production of solar thermal and solar photovoltaic energy in absolute values and in per capita primary energy production.

#### *Solar energy rank in the primary renewable energy production*

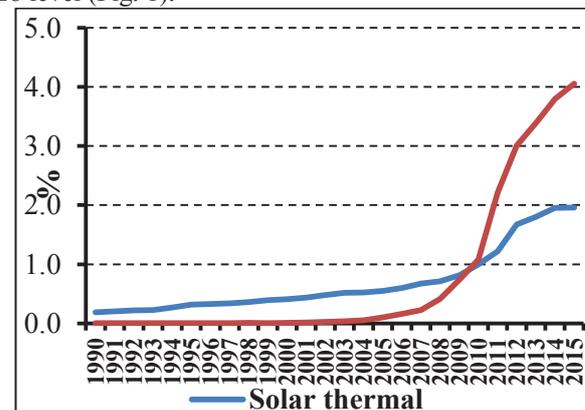
In the early 90, the places occupied by solar thermal energy and solar photovoltaic energy were modest. At EU-28 level, in the total primary renewable energy production, they have represented 0.1877% and, respectively, 0.0015%, being practically negligible. Although during the period from 1990 and 2000, there have been increases in the volume of primary production of both types of energy sources, in 2000, the share of solar thermal energy at EU-28 level has represented 0.4093% of the total primary renewable energy (an increase of 0.2216 percentage points) and the share of solar photovoltaic energy has been of 0.0098% (an increase of only 0.0083 percentage points).

The annual growth rates of primary production from the two sources based on solar energy have overtaken the growth rates of most renewable energy production obtained from other sources since 2000. In this context, their productions volumes begin to be significant. Thus, from a primary production of 426.7 TOE in 2000, the solar thermal energy has reached to 703.0 TOE in 2005, 1788.3 TOE in 2010 and 4252.0 TOE in 2015. In the

analysed period, the annual growth rates of the primary production based on solar thermal energy have ranged between a minimum of 7.03% in 2004 and a maximum of 35.23% in 2010.

Regarding the solar photovoltaic energy, this type of energy source has reached from a primary production of 10.2 TOE in 2000 to 125.6 TOE in 2005, 1935.0 TOE in 2010 and 8798.9 TOE in 2015. The annual growth rates of primary energy production from this source have evolved between a minimum of 14.09% in 2014 to a maximum of 101.37% in 2011. The explosive increase of the primary production of solar photovoltaic energy has led to the change in the ratio between the two energy sources. Thus, in 2009 and 2010 the primary production of solar photovoltaic energy has overtaken the primary production of solar thermal energy.

The annual growth rates of primary production of two energy sources have led to an increase of the production share of solar thermal and solar photovoltaic energy in the total primary renewable energy production at the EU-28 level (Fig. 1).



**Fig. 1.** Evolutions of shares of primary productions of solar thermal and solar photovoltaic energy in the total primary renewable energy production, in EU-28, in 1990-2015 period.

In the period between 2000 and 2010, the share of primary production of solar thermal energy in the total primary renewable energy production, at EU-28 level, has been almost linear with an annual average increase of 0.027 percentage points. In the last five years of the analysed period, we have noticed an exponential growth. However, in 2014 and 2015 a stabilization has occurred around the value of 1.95%.

The share of total production of solar photovoltaic energy in the total primary renewable energy production, at EU-28 level, has had a relatively similar trend but with a much higher intensity. If the increase has been almost linear between 2000 and 2006 with an annual average increase of 0.006 percentage points, after 2007, the increase has become explosive, so that in only 8 years, from a share of 0.2242% in the total primary renewable energy production in 2007, at EU-28 level, it has reached to 4.0548% in 2015. This change of share is the result of the increase of the primary production of solar photovoltaic energy from 324.5 TOE in 2007 to 8798.9 TOE in 2015 (an increase of 27.12 times).

\* Corresponding author: [marianzaharia53@gmail.com](mailto:marianzaharia53@gmail.com)

EU countries rank in the total primary production of solar thermal and solar photovoltaic energy

The statistical significances of the mean values of the two indicators have been determined and tested in order to see if the hierarchy and the EU-28 member states grouping by the total primary production of solar thermal energy and, respectively, solar photovoltaic energy bring relevant information in relation to the primary mean production from these energy sources (Table 1).

Taking into account that the standard deviation values (Std. Dev.) are much higher than the mean values (Mean), the 99% confidence level ( $\alpha=0.01$ ) has been chosen to test the statistical significance of the mean values. The critical value of *t* test (2-tailed) for the 99% confidence level is  $t_{\frac{\alpha}{2}, 27} = 2.771$ .

Excepting the primary mean production of solar thermal energy for 2000 for which the null hypothesis ( $H_{0,1}$ ) is rejected and the alternative hypothesis ( $H_{1,1}$ ) is accepted, for all other mean values the null hypothesis is accepted ( $H_{0,1}$ ) and, consequently, the obtained values are not statistically significant and cannot be used in analyses. This fact emphasizes a greater diversity and requires sorting and grouping of EU-28 member states by the primary productions of solar thermal and solar photovoltaic energy.

**Table 1.** Testing the statistical significance of primary mean production of solar thermal and solar photovoltaic energy, at eu-28 level

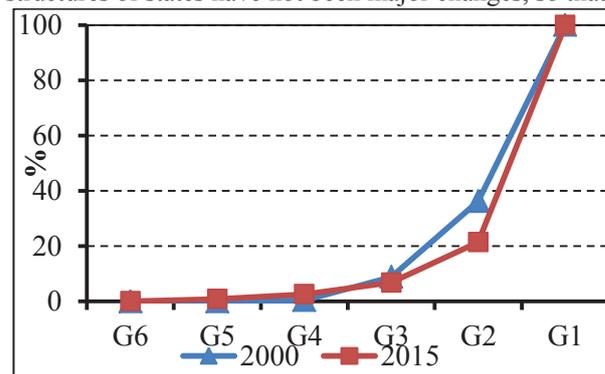
Year	Source	Mean	Std.Dev.	$t_c$	Acc.H.
2000	ST	15.24	29.13	2.768	$H_{1,1}$
	SP	0.36	1.03	1.852	$H_{0,1}$
2005	ST	25.10	53.49	2.483	$H_{0,1}$
	SP	4.48	20.76	1.142	$H_{0,1}$
2010	ST	63.86	128.36	2.632	$H_{0,1}$
	SP	69.10	212.91	1.717	$H_{0,1}$
2015	ST	151.86	473.85	1.696	$H_{0,1}$
	SP	314.24	717.47	2.324	$H_{0,1}$

In order to emphasize the distribution of EU-28 member states by groups depending on the primary productions of solar thermal energy, they have been sorted descending and, after that, six groups have been formed for each of the four years included in the analysis. The first group includes the first three states that contain the highest values of the primary production of solar thermal energy. The other groups contain five states. The primary means productions of energy have been determined for each group.

The graphical representation of the accumulated values corresponding to the primary means productions of solar thermal energy, at group level, highlights not only a high concentration of this type of energy but also an emphasis of it during the period between 2000 and 2015 (Fig. 2).

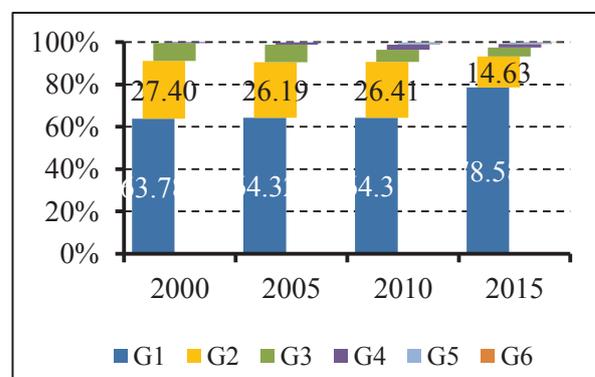
Some changes regarding the shares of primary production of solar thermal energy by groups of states in the total primary production recorded from this type of energy source at EU-28 level have been produced

between 2000 and 2015. However, in the groups structures of states have not been major changes, so that



**Fig. 2.** Concentration of primary productions of solar thermal energy, by groups of states, in 2000 and 2015.

the groups structure of states in 2015 (Table 2) does not fundamentally differ from their structure from 2000.



**Fig. 3.** Evolutions of shares of primary productions of solar thermal energy by groups of states, in 2000-2015 period.

In 2000, the share of primary production of solar thermal energy of the states from the first group (G1) in total primary energy production from this source has

**Table 2.** States groups structures in terms of the share of primary production of solar thermal energy, in 2000 and 2015

Year	Group	Countries
2000	G1	Germany, Greece, Austria
	G2	Cyprus, Spain, France, Portugal, UK
	G3	Italy, Netherlands, Denmark, Sweden, Croatia
	G4	Belgium, Finland, Ireland, Slovakia, Slovenia
	G5	Romania, Poland, Malta, Hungary, Luxemburg
	G6	Lithuania, Latvia, Estonia, Czech Republic, Bulgaria
2015	G1	Spain, Germany, Greece
	G2	Italy, Austria, France, Portugal, Cyprus
	G3	UK, Poland, Denmark, Netherlands, Belgium
	G4	Bulgaria, Czech Republic, Ireland, Sweden, Slovenia
	G5	Hungary, Croatia, Slovakia, Malta Luxemburg
	G6	Finland, Romania, Lithuania, Latvia, Estonia

\* Corresponding author: [marianzaharia53@gmail.com](mailto:marianzaharia53@gmail.com)

been of 63.78% that corresponded to a primary production of 272.1 TOE, the highest productions being recorded in Germany (110.9 TOE) and in Greece (98.8 TOE).

The second group (G2) has produced 27.4% of the total primary production of solar thermal energy, respectively 116.9 TOE. The highest production has been recorded in Cyprus (35.5 TOE) and lowest in the UK (11.2 TOE). In the same year, the states from the third group (G3) have produced 8.46% of total primary production of solar thermal energy, respectively 36.1 TOE, on the first places from the group being placed Italy (10.9 TOE) and Netherlands (10.8 TOE). Regarding the other 15 states (groups G4-G6), the share of their total primary production in the total primary production of solar thermal energy, at EU-28 level, has been only of 0.35%. In 2000, the primary production of solar thermal energy has been practically concentrated in the 13 states of the groups G1-G3.

In 2015, the share of the primary production of solar thermal energy of the states from the first group (G1) in the total primary production of energy from this source has reached to 78.58% (an increase of 14.8 percentage points). At the same time, the production shares of the states from the group G2 have been reduced from 27.4% to 14.63% (a decrease of 12.77 percentage points) and the production shares of the states from the group G3 have decreased from 8.46% to 4.21%. Also, we have noticed the fact that the share of the states from the groups G4-G6 has recorded significant increases reaching to 2.58%. Excepting Lithuania, Latvia and Estonia, in all other 12 states the primary production of solar thermal energy has been greater than 0.

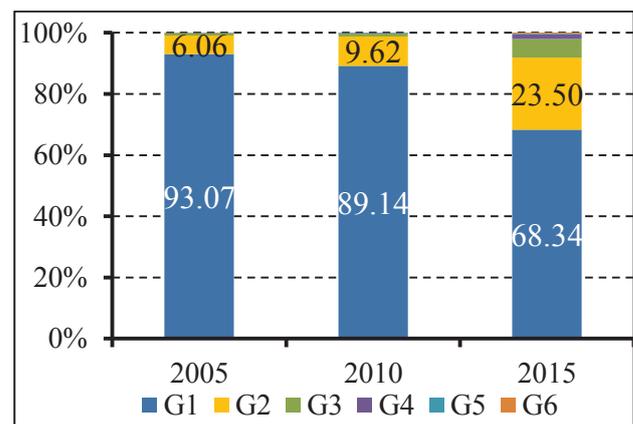
These changes of shares are due to the significant increases of the primary production of the solar thermal energy. If we consider only the first group (G1), the highest increase of production has been recorded in Spain, from 31.1 TOE to 2473.8 TOE (an increase of 79.54 times). Consequently, in 2015, Spain has produced 58.18% of total thermal solar energy, at EU-28 level. This fact has generated its transition from group G2 to group G1.

Italy has moved from group G3 to the group G2 due to an increase of the production from 10.9 TOE to 190.0 TOE (an increase of 17.43 times). At the same time, UK passes from group G2 to group G3 due to a lower annual increase rate of the production than the other states from group G2.

In the analysed period, due to the national energy policies, significant increases of the primary production of solar thermal energy have been recorded in states of EU-28 where the production from this energy source was practically null, in 2000. Thus, there have been recorded the following productions: 21.8 TOE in Bulgaria, 17.7 TOE in Czech Republic, 10.9 TOE in Slovenia, 10.7 TOE in Hungary, 5.5 TOE in Slovakia and 4.3 TOE in Malta. Romania with a production of only 0.5 TOE is placed in the group G6 with Finland and Baltic States.

The most spectacular increase of the solar energy use in the renewable energy production has been recorded, in the analysed period, by the solar photovoltaic energy, especially after 2005. In 2005, Germany has owned 87.89% of the total primary production of the solar photovoltaic energy at EU-28 level, with a production of 110.3 TOE. Spain, Netherlands, Italy, Austria and Luxembourg have owned, in turn, a percent of 9.96%, with a production ranged between 1.5 TOE and 3.5 TOE. In the other 22 states, the primary productions of solar photovoltaic energy have been practically insignificant.

The results are spectacular in most states for the period between 2005 and 2010, as well as for the period between 2010 and 2015 as a result of EU energy policies. This aspect has generated significant changes in the share of groups of states (Fig. 4). The groups' structures of states depending on these shares, in 2010 and 2015, are emphasized in Table 3. Excepting the first group (G1) that contains the same states both in 2010 and in 2015, in the other groups they have occurred changes.



**Fig. 4.** Evolutions of share of primary productions of solar photovoltaic energy by groups of states, in 2005-2015 period.

Although the primary production of solar photovoltaic energy generated by the states from the first group (G1) has increased from 1724.8 TOE in 2010 to 6013.4 TOE in 2015 (an increase of 3.48 times), its share in the total primary production, at EU-28 level, has decreased with 20.8 percentage points, reaching to 68.34%. However, it must be emphasized the fact that, in 2015, Germany and Italy have produced 37.8% and, respectively, 22.4% of the EU-28 production at this type of renewable energy.

Excepting Portugal, the other four states that are included in the group G2, in 2010, remain in this group also in 2015, with productions ranging between 194.7 TOE in Czech Republic and 624.2 TOE in France. The highest primary production of solar photovoltaic energy in this group, in 2015, is generated by UK whose production has increased from 3.5 TOE in 2010 to 650.1 TOE in 2015, representing 7.4% of the production of this energy type, at EU-28 level.

The primary production of solar photovoltaic energy for the third group (G3) has increased from 19.2 TOE to

\* Corresponding author: [marianzaharia53@gmail.com](mailto:marianzaharia53@gmail.com)

534.8 TOE (an increase of 27.9 times), in the period between 2010 and 2015. Unlike the first two groups, in this group, there are significant changes. Thus, must be emphasized the contributions of Romania and Bulgaria whose productions of solar photovoltaic energy have increased from very low values to 170.4 TOE and, respectively, 118.9 TOE that have placed them on the first two places in this group. However, in 2015, the states from this group have produced only 6.08% of EU-28 production.

In 2015, in the fourth group, Denmark with a production of 52.0 TOE, Slovenia with 23.6 TOE and Cyprus with 10.9 TOE are maintained. Also, in this group, are added Slovakia with a production of 43.5 TOE that has come from group G3 and Hungary that has reached from a production of 0.1 TOE in 2010 to a production of 10.5 TOE in 2015. In 2015, the primary production of solar photovoltaic energy for the entire group has been of 140.5 TOE that has represented only 1.6% of the total production of this type of renewable energy, at EU-28 level.

**Table 3.** States groups structures in terms of the share of primary production of solar photovoltaic energy, in 2000 and 2015

Year	Group	Countries
2000	G1	Germany, Spain, Italy
	G2	France, Czech Republic, Belgium, Portugal, Greece
	G3	Austria, Netherland, UK, Luxemburg, Slovakia
	G4	Bulgaria, Slovenia, Sweden, Cyprus, Denmark
	G5	Finland, Malta, Hungary, Romania, Poland
	G6	Lithuania, Latvia, Croatia, Ireland, Estonia
2015	G1	Germany, Italy, Spain
	G2	UK, France, Greece, Belgium, Czech Republic
	G3	Romania, Bulgaria, Netherlands, Austria, Portugal
	G4	Denmark, Slovakia, Slovenia, Cyprus, Hungary
	G5	Luxembourg, Sweden, Malta, Lithuania, Poland
	G6	Croatia, Finland, Ireland, Latvia, Estonia

Finally, in 2015, the groups G5 and G6 include states where the primary production of solar photovoltaic energy represents less than 0.1% of the primary production of solar photovoltaic energy, at the EU-28 level.

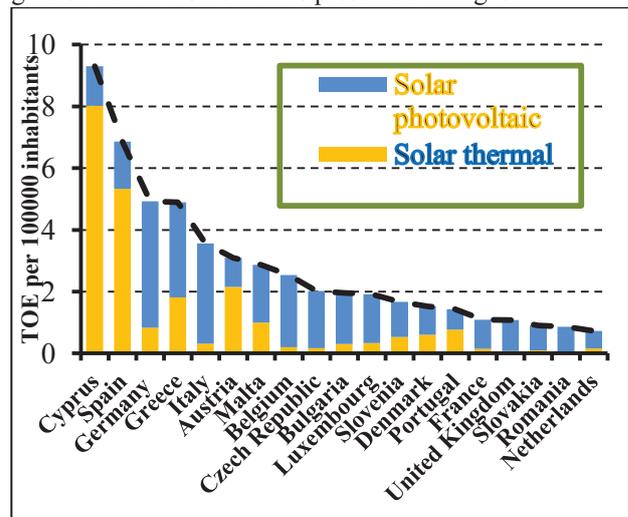
If we consider both primary production of solar thermal energy and primary production of solar photovoltaic energy, the first five producers of renewable energy based on solar radiation, in 2015, are: Germany with 40001.1 TOE, representing 30.66% of the total EU-28 production, Spain with 3184.6 TOE (24.40%), Italy with 2162.7 TOE (16.57%), France with 723.2 TOE (5.54%), and UK with 700.8 TOE (3.37%). Overall, these countries produce 82.54% of total primary energy production based on solar radiation at EU-28 level.

In this ranking, Romania has been placed, in 2015, on the 10<sup>th</sup> place, with a production of 170.9 TOE that have represented 1.31% of total EU-28 production.

*Aspects of per capita primary production of solar thermal and solar photovoltaic energy*

In the previous sections, the primary energy productions obtained from the solar radiations, by states and groups of states, in absolute values have been analysed. However, taking into account the fact that the sizes and the economic powers of the EU-28 member states are totally different, we emphasize some aspects of the primary production of solar thermal and solar photovoltaic energy reported to the number of inhabitants in each state. The chosen unit of measure was TOE per one hundred thousand inhabitants (TOE/HTI).

The hierarchy of EU-28 member states where the primary production of energy based on solar radiation is greater than 1 TOE / HTI is presented in Fig. 5.



**Fig. 5.** Primary production of solar thermal and solar photovoltaic energy per 100,000 inhabitants, in 2015.

A first observation is the fact that small states such as Cyprus and Malta due to their geographical positions and to their limited traditional resources of energy record significant values of this indicator. Thus, Cyprus is on the first place with a production of 9.3 TOE/HTI and Malta on the 7<sup>th</sup> place with a production of 2.86 TOE/HTI.

A second observation is that from the 2<sup>nd</sup> place to 6<sup>th</sup> place there are states that have been also placed on the first places at the primary production of solar thermal energy or solar photovoltaic energy: Spain with 6.86 TOE/HTI, Germany with 4.94 TOE/HTI, Greece with 4.9 TOE/HTI, Italy with 3.56 TOE/HTI and Austria with 3.1 TOE/HTI.

A third observation is the fact that important states with significant economic powers such as France and UK that have recorded productions of 1.08 TOE/HTI and, respectively, 1.08 TOE/HTI, in terms of primary production of solar thermal and solar photovoltaic energy per one hundred thousand inhabitants, are overtaken by much smaller states, among them three are former communist states: Czech Republic with productions of 2.02 TOE/HTI, Bulgaria with productions

\* Corresponding author: [marianzaharia53@gmail.com](mailto:marianzaharia53@gmail.com)

of 1.95 TOE/HTI and Slovenia with productions of 1.67 TOE/HTI.

We must also emphasize the fact that the shares of primary production of solar thermal and solar photovoltaic energy per one hundred thousand inhabitants in total significantly differ from one state to another. Thus, in states like Cyprus, Spain, Austria and Portugal, the primary production of solar thermal energy prevails, while in the other 12 states represented in Fig. 5 the primary production of solar photovoltaic energy predominates.

Finally, one last observation is about Romania that with a production of energy based on solar radiation of 0.86 TOE / HTI has been on 18<sup>th</sup> place. Also, we must highlight that 99.71% of this production is obtained from solar photovoltaic energy.

## 4 Conclusions

In the context of sustainable development, the renewable energy production is a necessity widely recognized by all EU-28 member states, as well as by most countries of the world. Although various renewable energy sources have been used since the last century, in the last 15-20 years the production of green energy has grown exponentially.

Among the renewable energy sources, the use of solar radiation, especially in the production of solar photovoltaic energy, has seen an unprecedented boom, an aspect that is due, to some extent, to the development of technologies and to the increase of the growth rates in this field. Although after 2010, the primary production of solar photovoltaic energy in 26 of the 28 EU member states has been higher than 0.1 TOE, in 2015, 60.2% of the primary production of the solar photovoltaic energy has been concentrated in two states: Germany and Italy that have produced 3329.9 TOE (37.8%) and, respectively, 1972.7 TOE (22.4%). Romania with a production of 170.4 TOE (1.94%) has been on the 9<sup>th</sup> place, in the EU-28.

Although the primary production of solar thermal energy has recorded significant increases, the growth rates have been lower than in the primary production of solar photovoltaic energy. In the period between 2000 and 2015, the primary production of solar thermal energy has increased from 426.6 TOE to 4252.1 TOE, at EU-28 level. However, the growth rates have significantly differed from one state to another. This fact has led to the increase of concentration. Thus, in 2015, 73.96% of the primary production of solar thermal energy (3145.0 TOE) has been provided by two states: Spain and Germany. Spain, with a production of 2473.8

TOE, has ensured 58.18% of the primary production of solar thermal energy.

In terms of the primary energy production based on solar radiation calculated per one hundred thousand inhabitants, Cyprus has been on the first place in EU-28 with a production of 9.3 TOE/HTI of which 86.17% is solar thermal energy. This fact is due, to some extent, to its geographical position that has led to the massive use of this type of energy. This phenomenon has been manifested, in time, also in Spain, Greece, Italy and Malta which are among the first seven EU-28 states, in this regard. However, we must emphasize the fact that Germany is on the third place with a production of 4.93 TOE/HTI. In this case, we cannot speak about a favorable geographical position, but about an economic power, a characteristic emphasized by the fact that 83.22% (4.10 TOE/HTI) of 4.93 TOE/HTI represents solar photovoltaic energy.

The characteristics of the primary productions evolutions of solar thermal and solar photovoltaic energy emphasize the conclusion that solar radiation is and will be an important source of renewable energy that will continue to develop based on technologies development, from the field.

## References

- [1] K. Traube, "Renewable Energy and Nature Conservation", *Energy & Environment*, vol. 15, issue 4, pp. 625-631, 2004.
- [2] H. Lund, "Renewable energy strategies for sustainable development", *Energy*, vol. 32, issue 6, pp. 912-919, 2007.
- [3] J. Andrei, J. Subic, and D. Dusmanescu, "Using dynamic programming for optimizing the investment strategy for an agricultural sheep holding: an investment case simulation", *Актуальні проблеми економіки*, vol. 4, no. 142, pp. 252-261, 2013.
- [4] A. G. Simionescu, M. C. Dragomir, "Using Renewable Energy for a Sustainable Development", *Annals of "Dunarea de Jos" University of Galati Fascicle I. Economics and Applied Informatics*, issue 3, pp. 39-44, 2012.
- [5] A. L. Dumitrescu, "The Energy Union pillars: competitiveness, security and sustainability", *The Journal of Global Economics*, vol. 8, issue 4, 2016.
- [6] J. V. Andrei, R. A. Ion, G. H. Popescu, E. Nica, and M. Zaharia, "Implications of agricultural bioenergy crop production and prices in changing the land use paradigm—the case of Romania", *Land Use Policy*, vol. 50, pp. 399-407, 2016.
- [7] European Commission, DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=en>, accessed on January 2017.
- [8] European Commission, State of the Energy Union 2015, <https://ec.europa.eu/transparency/regdoc/rep/1/2015/EN/1-2015-572-EN-F1-1.PDF>, accessed on January 2017.
- [9] Eurostat Database, Primary production - all products - annual data (nrg\_109a), [http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg\\_109a&lang=en](http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_109a&lang=en), accessed on January 2017.

\* Corresponding author: [marianzaharia53@gmail.com](mailto:marianzaharia53@gmail.com)