ECONOMIC-ENERGETIC PARAMETERS OF BIOMETHANE PRODUCTION FROM THE AGRICULTURAL PLANT BIOMASS[1]

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Abstract

At the beginning of 21st century, one of the biggest issues that Serbia is facing, as well as many other countries, among which are also EU member states, is a production of energy. Currently used resources (oil, fossil fuels and hydro-energy) are limited and most often non-renewable. Consequently, actual problem of energy deficiency could be solved by optimization and research of new energy sources (solar and wind energy, energy from biogas, geothermal and tidal energy, etc.), or renewable energy that is inexhaustible at the Earth. In EU countries, biogas production becomes so popular. According to that, there are established a conditions at the agricultural holdings, in order to increase their use of biomass residues for the production of heat and electricity. Also, organization of much more energy independent holdings is strongly supported. Economic parameters are very important for the use of certain procedures in practice. Here are considered, before all, price of methane, especially specific price compared to the primary energy unite, usually in kWh. Specific price is depending on costs of production of biogas, size of plant for methane production and applied technology. Costs of methane production are influenced by many factors, mostly by the used organic substrates (raw material) and plant size (capacity). In this research, organic substrate represents the waste from the agricultural plant production (straw and other harvest residues), as well as the use of energy plants parts (wheat, barley, corn, silage corn, millet and sunflower). Energetic parameters accentuate the obtained yield (per production unit, or 1 ha) of grown plant, as well as the volume of biogas that could be possibly abstracted from these crops, in other words the volume of energy which will be available for external

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use (selling). Sales revenues gained from produced electrical energy are important part, both for the economic profit and ecological balance of the biogas plant. Optimization of economic results of production is based on the concept of economic effectiveness (gaining of maximal economic effects per unit of invested assets). Starting from the assumption that the production surfaces are divided into the four parcels (with included crop production), installed power of CHP unit will be 269,58 kWh, calculated yield of the bio-methane will be 14.671,05 m^3/ha, while the variable costs will be around 5.035,74 €/ha.

Key words: *economic-energetic parameters, bio-methane, agricultural plant biomass.*

Introduction

For the purposes of this article, there were analyzed a data collected by field research (by interview of agricultural holdings specialized in crop production) at the Braničevo District (South and East Serbia Region)[4]. Throughout the field visits it was done the detailed insight into the soil condition. Also, previous knowledge has been analyzed, as well as current technologies for crop production on sandy soils were reconsidered[5]. According to this, selection of crops that possess the energetic potential for bio-methane production was based on several crucial requirements:

- To enable the fastest possible respond in crop production as it could provide obtaining the large volume of plant biomass that could be used for bio-methane production;
- To determine the crop rotation that will ensure competitiveness of grown crops in relation to weed plants;
- To select and define potential crops, adequate mechanical operations of land and crops cultivation within the existing production frame

[4] According the fact that the achieved yields in crop production within the Region of South and East Serbia are much lower than the average yields achieved at the Republic level, authors intention was to direct the research in order to find the alternative solution for optimization of economic results of production.

[5] Agricultural land that was the object of analysis (total arable surface of 140 ha), had not been cultivated for a long time period, so it was in weedy condition, characterized by large deposit of weed seeds in surface layer. In order to decrease the production risks, as well as to intensify the production process, there are suggested the concept of crop rotation that implies the division of complete production surface into the four plots (size of each plot is around 35 ha).

characteristic for the Serbia, that will enable quit a economic production in given business conditions;
- To determine production technology in line to crops which are achieving a great biomass in conditions of irrigation, as well as to define the alternative crops that could endure relatively easy the conditions of rain fed crop production.

Considering the fact that in Serbia there are limited information about the production of energy from biogas, main goal of article is analysis of economic feasibility and energy balance of methane production from the energy crops and harvest residues. For the crop production purposes, all costs derived from the used production technology (throughout the costs of certain operations and used inputs) are taken. Compared to the full price calculation, which is based on the determination of costs emerged from all sources, in the calculation based on variable costs is determining the ability of obtained products to cover the incurred expenses. In presented case it does not derive from their market prices, than from their conversion into the price of energy that will be gained from the methane production per 1 ha of production surface under the certain crops. Based on the calculation upon the variable costs, it could be done the assessment of the economic effects of the production of same crop in regard to different levels of production intensity, as well as to calculate the production risks due to variable costs increase. In relatively simple way, it will be obtained the marginal values of the product price (in this case wheat, barley, corn, silage corn, millet and sunflower), that will provide profitability of its production, i.e. under which level of variable costs increase and current price of produced product, its production will be economically justified.

Methodology

The production efficiency and orientation of agricultural holding towards the development continuity implies a positive difference between the obtained value of final products and total costs of production (Subić et al., 2010).

Analytical calculations based on variable costs covering (so called contribution margin) are considering the cutting down of totally achieved incomes for realized variable costs within a certain line of agricultural production. In plant (primarily crop) production they are usually expressed per the unit of production surface (hectare). It could be presented by following formula (Subić, Jeločnik, 2013; Jeločnik et al., 2016):

$CM = PV - VC$, where: $PV = (q \times p) + s$

Where:

CM - contribution margin;
PV - obtained production value (of primary and secondary products);
VC - achieved variable costs;
q - products' quantity per the unit of production surface;
p - price of product per the unit of measure;
s - subsidies per the unit of production surface.

Totally achieved contribution margin at the agricultural holding was expressed by the sum of individual contribution margins of present production lines, where achievement of total profit does not mean simple generating of profit within the each production line (method enables marking of the most profitable lines), (Jeločnik et al., 2015). Mentioned method makes much simpler insight into achieved business results at the farm during the one production cycle, as well as easier determining the size of the deviation of achieved results in the case of production volume oscillations (Subić et al., 2010).

Negligible impact of agricultural producers on the selling prices of their final products (they are created by the market), assigns to farm the possibility to find, by the mentioned method, more efficient way of costs analysis in line to potential changes in structure, volume and way of production (Subić et al., 2015).

Use of method leads to the optimal structure of the production and contributes the assessment of production risks that affect the holding (Ivanović, Jeločnik, 2016). Besides the evaluation of economic effects of production of certain crop under the different levels of intensity, method could compare economic efficiency of different production lines under the identical fixed costs (Jeločnik et al., 2013).

Expressed correlation between the production results and production uncertainty, implies the need of their assessment. As simple, but very efficient method for the holding could be the determination of critical (breakeven points) production levels (critical price, yield and variable costs), points in which the contribution margin equals the zero (Nastić et al., 2014).

On the other side, by the focus on the energy balance of biogas that could be gained from agricultural plant mass, it should be mentioned that natural gas is consisted by almost the 99% of methane, why its concentration is something smaller within the biogas. In this research, assumption was that the biogas could be used in the production of electric energy by its use as the driving fuel for the motor that runs the generator of electric power. For this is usually used the classical internal combustion engine (ICE) with small modifications for mentioned purpose.

Electric efficiency of such a this systems is around 30%, where for the systems larger than 50 kW that percentage could be increased, while for the systems smaller than 30 kW that percentage could be decreased (Babić et al., 2010).

Having in mind the fact that operational time of work of the system mostly depends on the biogas availability during the whole year, in case that the biogas production is provided during the complete year, operational time of work will be around 8.000 hours at the year level.

Currently, worldwide is popular the technology of combined heat and power production (CHP systems). As the efficiency of mentioned system is between the 85-95%, CHP system capacity could be defined by the next formula (Hiliborn, 2006): CHP system capacity (in kWh) = [volume of biogas (in m^3/year) x heat power of biogas (in MJ/Nm^3) / 3,6] / [operational time of work (in h/year) x electric efficiency].

In this case, CHP system capacity was determined by the following formula: CHP system capacity (in kWh) = methane production (in m^3) x 10^6 kWh/m^3 x system efficiency[7] (in %) x operational time of work (in h/year).

Research results with discussion

According to data of the Statistical office of the Republic of Serbia (SORS), in the period 2007-2016, in the Region of South and East Serbia were gained much lower yields than those one achieved at the level of entire Republic. Yields are referring to the selected crops grown in the system of rain fed agricultural production (without application of irrigation), (Table 1.).

[6] Each m^3 of methane contains 10 kWh of energy.

[7] According to used system type, system efficiency in obtaining the electric energy ranges from 30 to 42% (in this case all calculations were based on system efficiency of 42%).

Table 1. *Review of achieved yields during the period 2007-2016.*

Year	Wheat[2] yield (t/ha)	Barley yield (t/ha)	Corn yield (t/ha)	Sunflower yield (t/ha)	Silage corn yield (t/ha)
Republic of Serbia[1]					
2007	3,70	2,80	3,90	1,90	17,50
2008	4,30	3,70	5,90	2,40	18,10
2009	4,10	3,20	6,40	2,40	21,90
2010	3,40	2,90	7,10	2,20	22,90
2011	4,20	3,60	6,20	2,50	21,10
2012	4,00	3,40	3,60	2,00	14,90
2013	4,30	4,00	6,00	2,70	20,70
2014	3,90	3,60	7,50	2,90	19,20
2015	4,10	3,80	5,40	2,60	17,30
2016	4,80	4,30	7,30	3,10	21,30
Lowest yield	3,40	2,80	3,60	1,90	14,90
Average yield	4,08	3,53	5,93	2,47	19,49
Highest yield	4,80	4,30	7,50	3,10	22,90
Region of South and East Serbia					
2007	2,60	1,90	2,20	1,70	8,70
2008	3,70	2,90	4,40	2,10	10,80
2009	3,50	2,50	4,90	2,60	12,10
2010	2,90	2,40	5,30	2,20	12,10
2011	3,40	2,80	4,20	1,50	12,30
2012	3,30	2,60	3,10	1,50	10,40
2013	3,40	3,00	4,10	2,20	14,50
2014	3,10	2,70	5,20	2,20	13,00
2015	3,40	3,00	4,40	2,00	10,80
2016	3,80	3,70	5,50	2,30	13,80
Lowest yield	2,60	1,90	2,20	1,50	8,70
Average yield	3,31	2,75	4,33	2,03	11,85
Highest yield	3,80	3,70	5,50	2,60	14,50

Source: *Authors calculations based on the SORS data - Crop production, data set for the period 2007-2016 (http://www.stat.gov.rs/WebSite/public/ReportView.aspx).*

[1] From 1999 without the data for Kosovo and Metohija.

[2] SORS does not register the data for the millet.

In upcoming period, by the use of irrigation, it could be possible to achieve much larger yields (Table 2.).

Table 2. *Planned yields of selected crops in the production system that includes irrigation*

Year	Wheat	Barley	Corn	Sunflower	Silage corn
	yield (t/ha)	yield (t/ha)	yield (t/ha)	yield (t/ha)	yield (t/ha)
Region of South and East Serbia					
Lowest yield	3,43	2,46	3,15	2,15	13,40
Average yield	4,26	3,46	6,04	2,83	17,82
Highest yield	4,76	4,54	7,48	3,54	21,30
Primary product	**4,8**	**4,5**	**7,5**	3,5	**21,3**
Secondary product	**2,4**	**2,0**	**11,2**	4,4	**-**
Total	**7,2**	**6,5**	**18,7**	**7,9**	**21,3**

Source: *Authors calculations based on the SORS data - Crop production, data set for the period 2007-2016 (http://www.stat.gov.rs/WebSite/public/ReportView.aspx) and field research in the period 2007-2016 (IAE, 2017).*

Calculation of wheat production

Table 3. *Starting parameters in wheat production*

Line of production	**Wheat**		District:	Braničevo District
Type of production	Crop production		NUTS level:	Serbia - South (South and East Serbia)
Unit of production capacity:	1	ha	Production year	Growing average for the period 2018-2020
Production technology	With irrigation		Average rate: EUR 1 = 118,83 RSD	

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Table 4. *Contribution margin in wheat production*

Element	Volume	UM	Price (RSD/ UM)	Total RSD/ha	Total EUR/ha	Total RSD/35 ha	Total EUR/35 ha
A. Incomes							
Wheat (grain)	4.800,00	kg	18,80	90.240,00	759,43		
Straw	2.400,00	kg	4,80	11.520,00	96,95		
Complete plant	7.200,00	kg					
Subsidies				4.000,00	33,66		
Production value (total A)				**105.760,00**	**890,05**	**3.701.600,00**	**31.151,62**
B. Variable costs							
Seed	250,00	kg	37,00	9.250,00	77,85		
Fertilizers				19.300,00	162,42		
Pesticides				6.569,92	55,29		
Mechanization				36.249,70	305,07		
Irrigation				28.180,00	237,15		
Variable costs (total B)				**99.549,62**	**837,78**	**3.484.236,68**	**29.322,35**
C. Contribution margin (A-B)				**6.210,38**	**52,26**	**217.363,32**	**1.829,27**

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Table 5. *Critical values in wheat production*

Description	RSD (kg/ha)	EUR (kg/ha)
Expected yield (EY)	4.800,00	40,40
Expected price (EP)	18,80	0,16
Subsidies (S)	4.000,00	33,66
Variable costs (VC)	99.549,62	837,78
Critical price: CP = (VC – S) / EY	**19,91**	**0,17**
Critical yield: CY = (VC – S) / EP	**5.082,43**	**5.082,43**
Critical variable costs: CVC = (EY x EP) + S	**94.240,00**	**793,10**

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

According to the analytical calculations based on variable costs in wheat production (with irrigation), it could be concluded:

- Gained yield of grains amounts 4,8 t/ha (straw 2,4 t/ha, or complete plant 7,2 t/ha);
- Gained income amounts 890,05 EUR/ha (or 31.151,62 EUR/35ha);
- Gained variable costs amount 837,78 EUR/ha (or 29,322,35 EUR/35 ha);
- Positive contribution margin was obtained in amount of 52,26 EUR/ha (or 1.829,27 EUR/35 ha);
- In the structure of variable costs, costs of mechanization and irrigation are dominating (with the share of 37%, or 28%).

Based on previous preview of achieved contribution margin in wheat production, with certain dose of safety it could be claimed that it leaves little space for covering of all fixed costs and obtaining of profit after all variable costs are covered.

Calculation of barley production

Table 6. *Starting parameters in barley production*

Line of production	**Barley**		District:	Braničevo District
Type of production	Crop production		NUTS level:	Serbia - South (South and East Serbia)
Unit of production capacity:	1	ha	Production year	Growing average for the period 2018-2020
Production technology	With irrigation		Average rate: EUR 1 = 118,83 RSD	

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Table 7. *Contribution margin in barley production*

Element	Volume	UM	Price (RSD/ UM)	Total RSD/ha	Total EUR/ha	Total RSD/35 ha	Total EUR/35 ha
A. Incomes							
Barley (grain)	4.500,00	kg	18,50	83.250,00	700,61		
Straw	2.035,00	kg	4,80	9.768,00	82,20		
Complete plant	6.535,00	kg					
Subsidies				4.000,00	33,66		
Production value (total A)				**97.018,00**	**816,48**	**3.395.629,85**	**28.576,66**
B. Variable costs							
Seed	200,00	kg	37,00	7.400,00	62,28		
Fertilizers				14.393,00	121,13		
Pesticides				6.569,92	55,29		
Mechanization				37.669,30	317,01		
Irrigation				22.544,00	189,72		
Variable costs (total B)				**88.576,22**	**745,43**	**3.100.167,59**	**26.090,13**
C. Contribution margin (A-B)				**8.441,78**	**71,04**	**295.462,26**	**2.486,53**

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Table 8. *Critical values in barley production*

Description	RSD (kg/ha)	EUR (kg/ha)
Expected yield (EY)	4.500,00	37,87
Expected price (EP)	18,50	0,16
Subsidies (S)	4.000,00	33,66
Variable costs (VC)	88.576,22	745,43
Critical price: CP = (VC – S) / EY	**18,79**	**0,16**
Critical yield: CY = (VC – S) / EP	**4.571,69**	**4.571,69**
Critical variable costs: CVC = (EY x EP) + S	**87.250,00**	**734,27**

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Based on analytical calculations of contribution margin in barley production (with irrigation), following could be concluded:

- Achieved yield of grains amounts 4,5 t/ha (straw 2,0 t/ha, or complete plant 6,5 t/ha);
- Obtained income is in value of 816,48 EUR/ha (or 28.576,66 EUR/35ha);
- Gained variable costs are 745,43 EUR/ha (or 26,090,13 EUR/35 ha);
- Positive contribution margin was achieved in amount of 71,04 EUR/ha (or 2.486,53 EUR/35 ha);
- Within the structure of variable costs, costs of mechanization and irrigation are dominating (with the share of 43%, or 26%).

According to afore-presented contribution margin in barley production, it is obvious that it leaves, after covering variable costs, not enough space for covering of all fixed costs and obtaining the profit.

Calculation of corn production

Table 9. *Starting parameters in corn production*

Line of production	**Corn**		District:	Braničevo District
Type of production	Crop production		NUTS level:	Serbia - South (South and East Serbia)
Unit of production capacity:	1	ha	Production year:	Growing average for the period 2018-2020
Production technology	With irrigation		Average rate: EUR 1 = 118,83 RSD	

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Table 10. *Contribution margin in corn production*

Element	**Volume**	**UM**	**Price (RSD/ UM)**	**Total RSD/ha**	**Total EUR/ha**	**Total RSD/35 ha**	**Total EUR/35 ha**
A. Incomes							
Corn (grain)	7.500,00	kg	17,00	127.500,00	1073,00		
Corn stalk	11.250,00	kg	1,50	16.875,00	142,02		
Complete plant	18.750,00	kg					
Subsidies				4.000,00	33,66		
Production value (total A)				**148.375,00**	**1.248,68**	**5.193.125,00**	**43.703,87**
B. Variable costs							
Seed	2,40	s.u.	3.700,00	8.880,00	74,73		
Fertilizers				24.420,00	205,51		
Pesticides				12.000,00	100,99		
Mechanization				31.558,80	265,59		
Irrigation				39.452,00	332,02		
Variable costs (total B)				**116.310,80**	**978,84**	**4.070.878,00**	**34.259,35**
C. Contribution margin (A-B)				**32.064,20**	**269,84**	**1.122.247,00**	**9.444,51**

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Table 11. *Critical values in corn production*

Description	**RSD (kg/ha)**	**EUR (kg/ha)**
Expected yield (EY)	7.500,00	63,12
Expected price (EP)	17,00	0,14
Subsidies (S)	4.000,00	33,66
Variable costs (VC)	116.310,80	978,84
Critical price: CP = (VC – S) / EY	**14,97**	**0,13**
Critical yield: CY = (VC – S) / EP	**6.606,52**	**6.606,52**
Critical variable costs: CVC = (EY x EP) + S	**131.500,00**	**1.106,67**

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

According to analytical calculations based on variable costs related to corn production (with irrigation), next conclusion could be made:

- Achieved yield of grains amounts 7,5 t/ha (corn stalk 11,2 t/ha, or complete plant 18,7 t/ha);
- Gained income amounts 1.248,68 EUR/ha (or 43.703,87 EUR/35ha);
- Obtained variable costs are 978,48 EUR/ha (or 34.259,35 EUR/35 ha);
- Positive contribution margin was achieved in amount of 269,84 EUR/ha (or 9.444,51 EUR/35 ha);
- Within the structure of variable costs dominant are the costs of irrigation and mechanization (with the share of 34%, or 27%).

According to gained contribution margin in corn production, it is obvious that it leaves enough space for covering of all fixed costs and obtaining the profit, after all variable costs are covered.

Calculation of silage corn production

Table 12. *Starting parameters in silage corn production*

Line of production	**Silage corn**		District:	Braničevo District
Type of production	Crop production		NUTS level:	Serbia - South (South and East Serbia)
Unit of production capacity:	1	ha	Production year:	Growing average for the period 2018-2020
Production technology	With irrigation		Average rate: EUR 1 = 118,83 RSD	

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Table 13. *Contribution margin in silage corn production*

Element	**Volume**	**UM**	**Price (RSD/ UM)**	**Total RSD/ha**	**Total EUR/ha**	**Total RSD/35 ha**	**Total EUR/35 ha**
A. Incomes							
Silage corn (whole plant)	21.300,00	kg	5,00	106.500,00	896,27		
Subsidies				4.000,00	33,66		
Production value (total A)				**110.500,00**	**929,94**	**3.867.500,00**	**32.547,78**
B. Variable costs							
Seed	2,64	s.u.	3.700,00	9.768,00	82,20		
Fertilizers				26.862,00	226,06		
Pesticides				12.000,00	100,99		
Mechanization				29.198,20	245,72		
Irrigation				22.544,00	189,72		
Variable costs (total B)				**100.372,20**	**844,70**	**3.513.027,00**	**29.564,64**
C. Contribution margin (A-B)				**10.127,80**	**85,23**	**354.473,00**	**2.983,14**

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Table 14. *Critical values in silage corn production*

Description	RSD (kg/ha)	EUR (kg/ha)
Expected yield (EY)	21.300,00	179,25
Expected price (EP)	5,00	0,04
Subsidies (S)	4.000,00	33,66
Variable costs (VC)	100.372,20	844,70
Critical price: CP = (VC – S) / EY	**4,52**	**0,04**
Critical yield: CY = (VC – S) / EP	**19.274,44**	**19.274,44**
Critical variable costs: CVC = (EY x EP) + S	**110.500,00**	**929,94**

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Based on analytical calculations of contribution margin in silage corn production (with irrigation), next conclusion could be made:

- Achieved yield of whole plant is 21,3 t/ha;
- Obtained income amounts 929,94 EUR/ha (or 32.547,78 EUR/35ha);
- Obtained variable costs are 844,70 EUR/ha (or 29.564,64 EUR/35 ha);
- Positive contribution margin was achieved, with value of 85,23 EUR/ha (or 2.983,14 EUR/35 ha);
- Within the structure of variable costs dominant are the costs of mechanization and irrigation (with the share of 29%, or 22%).

Based on achieved contribution margin in silage corn production, it could be concluded that it leaves limited space for covering all fixed costs and profit obtaining.

Calculation of millet production

Table 15. *Starting parameters in millet production*

Line of production	**Millet**		District:	Braničevo District
Type of production	Crop production		NUTS level:	Serbia - South (South and East Serbia)
Unit of production capacity:	1	ha	Production year:	Growing average for the period 2018-2020
Production technology	With irrigation		Average rate: EUR 1 = 118,83 RSD	

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Table 16. *Contribution margin in millet production*

Element	Volume	UM	Price (RSD/ UM)	Total RSD/ha	Total EUR/ha	Total RSD/35 ha	Total EUR/35 ha
A. Incomes							
Millet (grain)	5.130,00	kg	20,00	102.600,00	863,45		
Harvesting residues	12.825,00	kg					
Whole plant	**17.955,00**	kg					
Subsidies				4.000,00	33,66		
Production value (total A)				**106.600,00**	**897,12**	**3.731.000,00**	**31.399,04**
B. Variable costs							
Seed	2,00	s.u.	4.500,00	9.000,00	75,74		
Fertilizers				12.210,00	102,76		
Pesticides				12.000,00	100,99		
Mechanization				29.198,20	245,72		
Irrigation				16.908,00	142,29		
Variable costs (total B)				**79.316,20**	**667,50**	**2.776.067,00**	**23.362,59**
C. Contribution margin (A-B)				**27.283,80**	**229,61**	**954.933,00**	**8.036,45**

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Table 17. *Critical values in millet production*

Description	RSD (kg/ha)	EUR (kg/ha)
Expected yield (EY)	5.130,00	43,17
Expected price (EP)	20,00	0,17
Subsidies (S)	4.000,00	33,66
Variable costs (VC)	79.316,20	667,50
Critical price: CP = (VC – S) / EY	**14,68**	**0,12**
Critical yield: CY = (VC – S) / EP	**3.765,81**	**3.765,81**
Critical variable costs: CVC = (EY x EP) + S	**106.600,00**	**897,12**

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Based on analytical calculations of contribution margin in millet production (with irrigation), it can be concluded:

- A grain yield of 5,1 t/ha has been realized (12,8 t/ha of harvest residues, or 17,9 t/ha of whole plant);
- Gained income amounts 897,12 EUR/ha (or 31.399,04 EUR/35 ha);
- Obtained variable costs are 667,50 EUR/ha (or 23.362,59 EUR/35 ha);
- Positive contribution margin has been achieved in amount of 229,61 EUR/ha (or 8.036,45 EUR/35 ha);
- In the structure of variable costs, the mechanization and irrigation costs are dominant with a share of 37%, or 21%.

Based on previous data for contribution margin in millet production, with some certainty, it can be claimed that contribution margin leaves enough space to cover fixed costs and to achieve positive financial result, after covering all variable costs.

Calculation of sunflower production

Table 18. *Starting parameters in sunflower production*

Line of production	**Sunflower**		District:	Braničevo District
Type of production	Crop production		NUTS level:	Serbia - South (South and East Serbia)
Unit of production capacity:	1	ha	Production year:	Growing average for the period 2018-2020
Production technology	With irrigation		Average rate: EUR 1 = 118,83 RSD	

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Table 19. *Contribution margin in sunflower production*

Element	**Volume**	**UM**	**Price (RSD/ UM)**	**Total RSD/ha**	**Total EUR/ha**	**Total RSD/35 ha**	**Total EUR/35 ha**
A. Incomes							
Sunflower (grain)	3.500	kg	35,65	124.775,00	1.050,07		
Harvest residues	4.375	kg		0,00	0,00		
Whole plant	7.875	kg		0,00	0,00		
Subsidies				4.000,00	33,66		
Production values (total A)				**128.775,00**	**1.083,73**	**4.507.125**	**37.930,68**
B. Variable costs							
Seed	2,00	s.u.	6.600,00	13.200,00	111,09		
Fertilizers				22.200,00	186,83		
Pesticides				12.000,00	100,99		
Mechanization				33.031,95	277,99		
Irrigation				33.816,00	284,59		
Variable costs (total B)				**114.247,95**	**961,48**	**3.998.678,25**	**33.651,74**
C. Contribution margin (A-B)				**14.527,05**	**122,26**	**508.446,75**	**4.278,94**

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Table 20. *Critical values in sunflower production*

Description	**RSD (kg/ha)**	**EUR (kg/ha)**
Expected yield (EY)	3.500,00	29,46
Expected price (EP)	35,65	0,30
Subsidies (S)	4.000,00	33,66
Variable costs (VC)	114.247,95	961,48
Critical price: CP = (VC – S) / EY	**31,50**	**0,27**
Critical yield: CY = (VC – S) / EP	**3.092,51**	**3.092,51**
Critical variable costs: CVC = (EY x EP) + S	**128.775,00**	**1.083,73**

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Based on analytical calculations of contribution margin in sunflower production (with irrigation), the following conclusions could be made:

- A grain yield of 3,5 t/ha has been achieved (as well as 4,4 t/ha of harvest residues, or 7,9 t/ha of whole plant);
- Obtained income amounts 1.083,73 EUR/ha (or 37.930,68 EUR/35 ha);
- Realized variable costs are 961,48 EUR/ha (or 33.651,74 EUR/35 ha);

- It has been gained a positive contribution margin cover in amount of 122,26 EUR/ha (or 4.278,94 EUR/35 ha);
- Within the structure of variable costs dominate the costs of irrigation and mechanization (with a share of 30%, or 29%).

Based on previous results for contribution margin in sunflower production, after covering of all variable costs there are left relatively small space to cover the fixed costs and to achieve the profit.

Energy potential (average for growing crops, for the period 2018-2018)

Table 21. *Energy potential of selected crops (with review of variable costs per each crop or production parcel)*

Parcel	Crop		Yield (t/ha)	Yield of biogas (m^3/t of mass)	Share of methane (%)	Yield of methane (m^3/t of mass)	Calculated yield of methane (m^3/ha)	Surface of the parcel (ha)	Daily input (t/day)	Total yield of methane (m^3/35 ha)	Total variable costs (EUR/35ha)
I	Barley	Grain	4,50	630,00	53,00%	333,90	1.502,55	35,00	0,43	52.589,25	26.090,13
		Straw	2,03	450,00	53,00%	238,50	485,35	35,00	0,20	16.987,15	
	Silage corn		21,30	220,00	52,00%	114,40	2.436,72	35,00	2,04	85.285,20	29.564,64
	Total (parcel I)								2,67	**154.861,60**	**55.654,77**
II	Wheat	Grain	4,80	610,00	53,00%	323,30	1.551,84	35,00	0,46	54.314,40	29.322,35
		Straw	2,40	450,00	53,00%	238,50	572,40	35,00	0,23	20.034,00	
	Millet		17,96	135,00	52,00%	70,20	1.260,44	35,00	1,72	44.115,44	23.362,59
	Total (parcel II)								2,41	**118.463,84**	**52.684,94**
III	Corn	Grain	7,50	600,00	53,00%	318,00	2.385,00	35,00	0,72	83.475,00	34.259,35
		Corn stalk	11,25	400,00	52,00%	208,00	2.340,00	35,00	1,08	81.900,00	
	Total (parcel III)								1,80	**165.375,00**	**34.259,35**
IV	Sunflower	Grain	3,50	600,00	53,00%	318,00	1.113,00	35,00	0,34	38.955,00	33.651,74
		Stalk	4,38	450,00	52,00%	234,00	1.023,75	35,00	0,42	35.831,25	
	Total (parcel IV)								0,76	**74.786,25**	**33.651,74**
Total (I+II+III+IV)									7,63	**513.486,69**	**176.250,80**
Suggestion for installed power of CHP unit (kWh)										**269,58**	

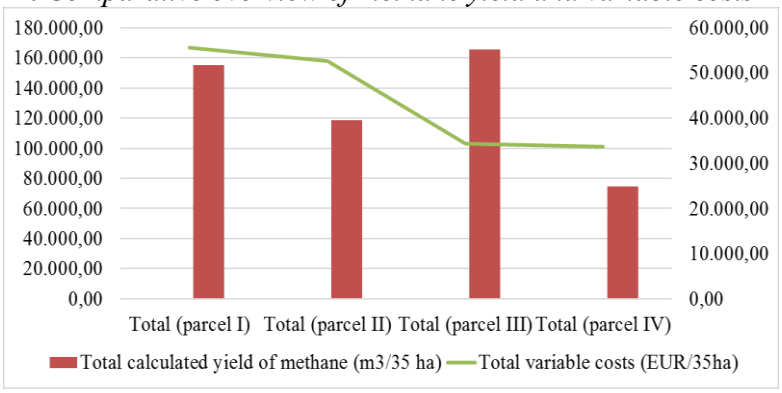
Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017); Assessment of the biogas yield that could be gained from the certain crop, in m^3/t of mass (GMT, 2017).*

Table 22. *Comparative overview of methane yield and variable costs*

Parcel	Total calculated yield of methane (m^3/35 ha)	Total variable costs (EUR/35ha)
Total (parcel I)	154.861,60	55.654,77
Total (parcel II)	118.463,84	52.684,94
Total (parcel III)	165.375,00	34.259,35
Total (parcel IV)	74.786,25	33.651,74
Total	**513.486,69**	**176.250,80**

Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Graph 1. *Comparative overview of methane yield and variable costs*



Source: *Authors calculations based on field research in the period 2007-2016 (IAE, 2017).*

Based on comparative overview of energy potential and realized variable costs in selected crops production (with irrigation), following conclusions could be made:

- Observed by individual culture:
  - The highest calculated yield of methane was registered at corn (at whole plant could be generated 165.375,00 m³/35 ha, i.e. at grain 83.475,00 m³/35 ha; or at corn stalk 81.900,00 m³/35 ha), where the total recorded variable costs amount 34.259,35 EUR/35 ha;
  - The lowest calculated yield of methane was registered at millet (at whole plant could be generated 44.115,44 m³/35 ha), where the total recorded variable costs amount 23.632,59 EUR/35 ha.
- Observed by parcels:
  - The highest calculated yield of methane was registered at the parcel no. III (163.375,00 m³/35 ha), where the total recorded variable costs amount 34.259,35 EUR/35 ha);
  - The lowest calculated yield of methane was registered at the parcel no. IV (74.786,25 m³/35 ha), where the total recorded variable costs amount 33.651,74 EUR/35 ha.

The proposal for installed power of CHP unit is 269,58 kWh.

Conclusion

Analysis of methane obtaining from the enery crops (growing under the system of irrigation), indicates the next results:

- Expected yields are under the average for the crops that are grown under the system of irrigation;
- Contribution margines are usually modest, but they allow covering of fixed costs and achieving of positive financial results;
- Within the structure of variable costs dominate the costs of mechanization (paid machine operation services) and irrigation, what imposes a need of consideration of possibility for investment in own mechanization and cheaper energy alternatives, or use of cheaper production technology and possibility to purchase the needed agricultural plant mass on the market;
- Calculated yield of methane is much under the planned expectations.

This case also includes certain crops whose growing is not usual for the biogas production, as their specific profitability per ton or unit of production surface is much lower than the use of the most common crops (such is the silage corn). According to that, yield of silage corn of 21,30 t/ha shows that it's possible to build the plant with the capacity of 300 kWh. On the other side, in line to the fact that the realized calculations are quite a conservative, it can be built the production facility with the total capacity of up to 350 kWh.

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