ECONOMIC EFFECTS OF THE SOLAR AND WIND ENERGY USE IN IRRIGATION OF VEGETABLE CULTURES[1]

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Abstract

Available climate and natural resources are allowing the successful vegetable production at wider territory of the Republic of Serbia. Production lines are organized at open field or in protected areas (greenhouses), and usually involve the use of agro technical measure of irrigation. Technological-technical complexity and much higher requirements for production intensity, more often contribute to a higher competitiveness of agricultural holdings dominantly oriented to the production of vegetables. In paper are presented the comparative results of field researches carried out in September and October 2015, and during the period August - November 2016. In last research, besides mobile robotic solar generator, in real terms was partially tested the use of mobile wind generator. Also, during the research are processed the data collected from the members of family agricultural holdings focused to the vegetable production, located in the Glogonj village at territory of the Pančevo city (within the wider area of the Upper Danube Basin) and in the Veliko Selo village at the territory of the Belgrade city (within the area of the Middle Danube Basin). For the research purposes, in accordance with the previously made agreement with holdings' members, observed holdings are marked with A and B. On the holding A, in the structure of variable costs, costs of irrigation are quite an equable (in the open field: from 357,72 to 364,29 EUR/ha, or in a greenhouse: from 378,50 to 554,00 EUR/ha). On the holding B, in the structure of variable costs, depending the production area costs of irrigation are visibly different (in the open field: from 85,00 to 341,50 EUR/ha, or in a greenhouse: from 2.550,00 to 3.278,00 EUR/ha). In order to

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increase economic effects in vegetable production, there is a possibility of used energy conversion (gasoline, diesel and electric power) into the cheaper and environmentally more acceptable solution (solar and wind energy).

Key words: *economic effects, solar energy, energy of wind, vegetable production, ecology.*

Introduction

On the territory of Republic of Serbia, a relatively large number of family agricultural holdings are involved in the production of vegetables. Accordingly, the economic effects in using solar and wind energy for operation of pumping systems in the process of irrigation could be of great importance for all farmers who deal with vegetables within the production structure.

Vegetable growing is the sector of agriculture, which expect from a farmer timely and adequate technical-technological and economic decisions, adjusted to planned production results (Jeločnik et al., 2015). It is well-known that farmers have a negligible effect on selling prices, but for that reason, falling into unwanted situations can compensate by proportionally large impact on the costs control (cost price) of their products and services (Vasiljević, Subić, 2010/b).

This research refers to the extension of field activities (previously done during the period September – October 2015)[4], which had realized in the period August – November 2016. Besides a mobile robotized electrical generator, there was also tested the work of a mobile wind power generator in real conditions. Research was also implied collecting data by interviewing members of selected family agricultural holdings (dominantly oriented to vegetable production). Surveyed holdings are specific by the applied production technology and approach in purchasing inputs and sale of manufactured vegetables. Cooperation in the implementation of field activities is continued with two holdings, located in the village Glogonj (territory of the city of Belgrade – narrow area of Middle Danube Region) and Veliko Selo (territory of the city of Belgrade - narrow area of Middle Danube Region). The research work was primarily focused to those vegetable crops in which production cycle (the process of irrigation) was already tested the mobile

[4] In the beginning of 2015, a mobile robotized solar electric generator at the Institute „Mihajlo Pupin"was developed, the leading national research institution in the field of information-communication technologies. It is energy efficient ecological device for the production of electrical energy by using solar energy (Subić, Jeločnik, 2016).

robotized solar electrical generator, during the years 2015 and 2016 (cabbage production in open field and tomato in protected areas – greenhouses).

Material and method of work

The assumption is that irrigation costs have the character of variable costs, and they mean the costs of fuel and lubricant (i.e. covering the costs of used energy and variable costs of irrigation system) and costs of defined compensation for irrigation. Initial expectations are to exceed the increase of variable costs by increasing the holdings' income by using irrigation. Although the irrigation costs have relatively small share in the structure of total variable costs, there was considered, from economic-ecological point of view, the possibility of used energy substitution (pump unit) with ecologically and economically acceptable alternative, energy produced from a solar electrical generator or wind power generator.

In accordance to their production structure, every agricultural holding should calculate the value of production and incurred costs (by simple, clear and easily applicable model of analysis) for every production line, whereby should be marked all lines of a higher profitability level (Jeločnik et al., 2015). Methodological simplicity and high level of practicality favours the analytical calculation based on variable costs in the process of business decision-making (Vasiljević, Subić, 2010/b), since it ensures a current economic analysis of current production, i.e. the sustainability evaluation of adopted production technology and achieved results (Subić et al., 2015).

Calculation of contribution margine (gross financial result) brings face to face the market value of realized production and the variable production costs of manufactured products in a holding. Character of variable costs in plant production (including vegetable growing) has: seed and planting material, fertilizers, pesticides, energy (fuel) and lubricants, external services of agricultural mechanization, engaged labour, packaging, etc. The contribution margin is defined as difference between total production values (value of the main product increased for value of the by-products and incentives) and the proportional variable costs (Vasiljević, Subić, 2010/a).

In vegetable production, the calculation of contribution margin can contribute to the comparison of two different lines (or phases) in vegetable production in terms of equal fixed costs, or comparison of two or more intensity levels of the same line of phase of vegetable production. Depending on utilized production areas, units of measurement adjust to every individual subject (m^2, are, hectare), but the obtained results of contribution margin adjust to hectares due

to make an easier comparison, whether it is about the production in open field or in a protected area.

In accordance to production specificities, decision-making in agriculture is often related to uncertainty and complex task to mitigate the risk of a potentially bad decision (Subić, 2010). Therefore, for the evaluation of production results in terms of uncertainty can be used also an analytical method of determining the critical price, critical yield and critical variable costs of some production line (values at which the contribution margin equates with zero), (Nastić et al., 2014).

All calculations were done based on the production value and variable costs realised on the actual production area in the observed holdings, and after all values were brought down to the area of 1 ha, owing to easier comparison. All variable costs and values of production were expressed in RSD and EUR.

From the methodology point of view, the calculation of these items in determined vegetable crops is identical, except in case if there are certain specificities in calculating the production values (products classification) or certain variable costs. All indicators were shown in tables, previously passing through a standard mathematically-statistical analysis, in order to accentuate in detail the arithmetical operation and the structure of calculation of contribution margin based on variable costs. As in the year before, the primary intention was to mark the amount of costs of consumed energy for the process of irrigation in the production of selected vegetable cultures, which would potentially substitute (reduce) by using renewable energy.

Considering the character of selected vegetable crops and applied technological approach in their production:

1. Comparative analytical calculations based on variable costs for selected holdings and selected vegetable crops for the years 2015 and 2016 were done,
2. In detail structure of generated variable costs is shown,
3. Critical values for every production line (price, yield and variable costs) are determined.

Theoretical and material basis is taken over from the available scientific and professional literature focused on a studied problem, and also from the in-depth interviews organized with members of selected family agricultural holdings in the villages Glogonj and Veliko Selo. Most of taken over data is directly connected to production cycles in 2015 and 2016, while some data are reflection of assessment of interviewee or generally accepted standard for

specific line of vegetable production. For justified reasons, after consultations with holding members, in research both farms are marked with A and B.

Research results with discussion

Field research (experiment), previously carried out in the year 2015, have been prolonged in 2016 in the same family agricultural holdings (villages Glogonj and Veliko Selo) and on same vegetable crops (tomato and cabbage) grown in the system with irrigation in the protected area (greenhouse) and in open field.

In the observed period, the selected family agricultural holdings haven't changed the technological approach in vegetable production. As in 2015, during the year 2016, the mobile robotized solar electrical generator has been tested (this time together with the mobile wind power generator) within the production of vegetables in the system which had included irrigation, since this system of production had significantly affected the stability and amount of realised yields. It is assumed that incomes from the cultivated vegetables sale cover all production costs, i.e. provide sufficient financial resources for payment of investments in purchase/construction of the irrigation system and making profit.

According to realised results in the *production of cabbage in open field*, along with the application of agro-technical measures of irrigation in 2015 and 2016 (*Tables 1-4*), *in the holding A* can be noticed:

- In both production years was realised a positive contribution margin (4,137. 39 EUR/ha in 2015, i.e. 5,811.83 EUR/ha in 2016). Since the technological approach in cabbage production hasn't changed, the difference among the realized contribution margins in amount of 1,674.44 EUR/ha has been a direct consequence of yield and a final product price, as well as the price of used inputs and the exchange rate of national currency in relation to euro,
- Taking into consideration the year 2015, the realised income in the production of cabbage are 1.7 times higher than the generated variable costs of production, while in the year 2016 were 2.1 times higher,
- In the structure of variable costs, the engaged labour costs dominate in both years. Seedlings costs and machining operation costs have the significant share. There can be noticed the considerable increase in the seedlings costs share, by focusing on 2016,

- In the structure of variable costs, the costs of energy (diesel), necessary for the process of irrigation, in both observed years, have a uniform and relatively modest share (6.38%, i.e. 6.77%),
- Critical values of production (where the contribution margin equates with zero) have the following values:
  - Critical price amounts 10.43 RSD/kg, or 9.63 RSD/kg;
  - Critical yield amounts 34,238.16 kg/ha, or 29,560.08 kg/ha;
  - Critical variable costs are 1,312,500.00 RSD/ha, or 1,485,000.00 RSD/ha.

Table 1. *Baseline (cabbage production in the open field)*

Region: Continental – South Banat District (Glogonj village)	Type of soil: Good
Period: Comparison of production results from two production cycles (2015. and 2016.)	Production area: 0.56 ha
2015.: 1.00 EUR = 120.00 RSD 2016.: 1.00 EUR = 123.00 RSD	Planting density: 60 x 45 cm

Source: *IAE, 2015; IAE, 2016.*

Table 2. *Contribution margin in cabbage production in the open field*

Element	Quantity	UM	Price/UM (in RSD)	Total RSD/0.56 ha	Total EUR/0.56 ha	Total EUR/ha
A-1 Incomes – 2015.						
Cabbage	36,750.00	kg	-	-	-	-
I class (90%)	33,075.00	kg	20.00	661,500.00	5,512.50	-
Spoilage (10%)	3,675.00	kg	-	-	-	-
Subsidies	-	-	-	-	-	-
Total A-1				**661,500.00**	**5,512.50**	**9,843.75**
A-2 Incomes – 2016.						
Cabbage	37,800.00	kg	-	-	-	-
I class (92%)	34,750.00	kg	22.00	764,500.00		
Spoilage (8%)	3,050.00	kg	-	-	-	-
Subsidies	-	-	-	-	-	-
Total A-2				**764,500.00**	**6,215.40**	**11,099.00**
Difference (A-2 – A-1)				**103,000.00**	**702.90**	**1,255.25**
B-1 Variable costs – 2015.						
Total B-1				**383,646.50**	**3,195.55**	**5,706.36**
B-2 Variable costs – 2016.						
Total B-2				364,180.00	2,960.83	5,287.17
Difference (B-2 – B-1)				**-19,466.50**	**-234.72**	**-419.19**
I Contribution margin – 2015. (A-1 – B-1)				**277,853.50**	**2,316.95**	**4,137.39**
II Contribution margin – 2016. (A-2 – B-2)				**400,320.00**	**3,254.57**	**5,811.83**
III Difference (II – I)				**122,466.50**	**937.62**	**1,674.44**

Source: *IAE, 2015; IAE, 2016.*

Table 3. *Structure of variable costs (VC) in cabbage production in the open field*

Element	Total RSD/ha (2015.)	Share in total VC (%)	Total RSD/ha (2016.)	Share in total VC (%)
Seedlings	131,250.00	19.17	149,999.70	23.07
Fertilizers	67,767.60	9.90	68,748.40	10.56
Pesticides	26,828.40	3.92	27,232.20	4.18
Packaging material	23,571.60	3.44	25,670.10	3.95
Mechanized operations	123,700.80	18.06	132,931.00	20.44
Costs of energy (irrigation)	43,714.80	6.38	43,999.60	6.77
Engaged labour	188,216.40	27.49	185,402.80	28.51
Other costs	79,713.60	11.64	16,338.00	2.52
Variable costs (total)	**684,763.20**	**100.00**	**650,321.80**	**100.00**

Source: *IAE, 2015; IAE, 2016.*

Table 4. *Critical values in cabbage production in the open field*

Element	RSD(kg)/ha - 2015.	RSD(kg)/ha - 2016.
Expected yield (EY)	65,625.00	67,500.00
Expected price (EP)	20.00	22.00
Subsidies (S)	-	-
Variable costs (VC)	684,763.20	650,321.80
Critical price: CP = (VC - S) / EY	**10.43**	**9.63**
Critical yield: CY = (VC - S) / EP	**34,238.16**	**29,560.08**
Critical variable costs: CVC = (EY x EP) + S	**1,312,500.00**	**1,485,000.00**

Source: *IAE, 2015; IAE, 2016.*

From everything above mentioned results the reasonable assurance that the contribution margin has left in both years enough space to cover fixed costs and realize a positive financial result, after the coverage of variable costs. The current year, 2016, was relatively better for the observed manufacturer (family agricultural holding A).

Despite of the fact that in the variable costs structure, the costs of irrigation (used energy – diesel) have very small and uniform value (364.29 EUR/ha in 2015, i.e. 357.72 EUR/ha in 2016), point out to possibility of their additional reduction by the conversion of used energy into cheaper and ecologically more acceptable solution (solar and wind energy), which will contribute to further improvement of realized economic results in a holding.

With direct comparison of realised results in the *production of tomato in protected area (greenhouse), in the holding A*, along with the use of agro-technical irrigation measures (*Tables 5-8*), can be noticed:

- The production line contributes to the realisation of the positive contribution margin (10,162.50 EUR/ha in 2015, or 11,955.50 EUR/ha in 2016). The growth of the contribution margin in amount of 1,792.00 EUR/ha is primarily the consequence of increase in prices of products in green market in the year 2016,
- realized incomes were 1.2 times higher than the generated variable costs of production in 2015, i.e. 1.3 times higher than in 2016,
- Reflection of the applied technological procedure on the structure of variable costs shows the ascendancy of relatively uniform share of engaged labour costs (22.37% in 2015, or 24.32% in 2016). In both observed years, the costs of seedlings, fertilizers and utilised equipment have relatively high share,
- Although the holding uses electrical energy from the public grid as a fuel for the irrigation system, the costs of energy have a humble share in the structure of total variable costs (1.27% in 2015, i.e. 0.82% in 2016),
- achieved critical values of production (balance of values and variable costs of production) show next results:
  - Critical price amounted 26.15 RSD/kg in 2015, i.e. 29.21 RSD/kg in 2016,
  - Critical yield was ranged from 154,064.80 kg/ha in 2015 to 151,886.60 kg/ha in 2016;
  - Critical variable costs were amounted 6,790,000.00 RSD/ha in 2015, or 7,312,500.00 RSD/ha in 2016.

Table 5. *Baseline (tomatoes production in greenhouse)*

Region: Continental – South Banat District (Glogonj village)	Type of soil: Good
Period: Comparison of production results from two 5 months production cycles (2015. and 2016.)	Size of greenhouse: 200 m^2
2015.: 1.00 EUR = 120.00 RSD 2016.: 1.00 EUR = 123.00 RSD	Planting density: 2.5 plants per m^2 (4 rows x 35m)

Source: *IAE, 2015; IAE, 2016.*

Table 6. *Contribution margin in tomatoes production in greenhouse*

Element	Quantity	UM	Price per UM (in RSD)	Total RSD/ 200 m^2	Total EUR/ 200 m^2	Total EUR/ha
A-1 Incomes – 2015.						
Tomatoes	4,000.00	kg	-	-	-	-
I class (75%)	3,000.00	kg	35.00	105,000.00	875.00	-
II class (20%)	800.00	kg	30.00	24,000.00	200.00	-
Spoilage(5%)	200.00	kg	-	-	-	-
Subsidies	-	-	-	-	-	-
Total A-1				**129,000.00**	**1,075.00**	**53,750.00**
A-2 Incomes – 2016.						
Tomatoes	**3,900.00**	kg	-	-	-	-
I class (70%)	**2,730.00**	kg	40.00	109,200.00	887.80	
II class (25%)	**975.00**	kg	35.00	34,125.00	277.44	
Spoilage(5%)	**195.00**	kg	-	-	-	-
Subsidies	**-**	**-**	-	-	-	-
Total A-2				**143,325.00**	**1,165.24**	**58,262.00**
Difference (A-2 – A-1)				**14,325.00**	**90.24**	**4,512.00**
B-1 Variable costs – 2015.						
Total B-1				**104,607.68**	**871.75**	**43,587.50**
B-2 Variable costs – 2016.						
Total B-2				**113,915.21**	**926.14**	**46,307.50**
Difference (B-2 – B-1)				**9,307.53**	**54.39**	**2,719.00**
I Contribution margin – 2015. (A-1 – B-1)				**24,392.32**	**203.25**	**10,162.50**
II Contribution margin – 2016. (A-2 – B-2)				**29,409.79**	**239.10**	**11,955.50**
III Difference (II – I)				**5,017.47**	**35.85**	**1,792.00**

Source: *IAE, 2015; IAE, 2016.*

Table 7. *Structure of variable costs (VC) in tomatoes production in greenhouse*

Element	Total RSD/ha (2015.)	Share in total VC (%)	Total RSD/ha (2016.)	Share in total VC (%)
Seedlings	874,980.00	16.73	937,499.85	16.46
Fertilizers	844,980.00	16.15	874,999.86	15.36
Pesticides	232,800.00	4.45	237,499.47	4.17
Packaging material	300,000.00	5.73	350,000.19	6.14
Mechanized operations	400,020.00	7.65	492,500.61	8.65
Equipment	948,660.00	18.14	956,748.12	16.80
Costs of energy (irrigation)	66,480.00	1.27	46,555.50	0.82
Engaged labour	1,170,060.00	22.37	1,384,998.45	24.32
Other costs	392,520.00	7.51	414,946.65	7.28
Variable costs (total)	**5,230,500.00**	**100.00**	**5,695,748.70**	**100.00**

Source: *IAE, 2015; IAE, 2016.*

Table 8. *Critical values in tomatoes production in greenhouse*

Element	RSD(kg)/ha - 2015.	RSD(kg)/ha - 2016.
Expected yield (EY)	200,000.00	195,000.00
Expected price (EP)	33.95	37.50
Subsidies (S)	-	-
Variable costs (VC)	5,230,500.00	5,695,748.70
Critical price: CP = (VC - S) / EY	**26.15**	**29.21**
Critical yield: CY = (VC - S) / EP	**154,064.80**	**151,886.60**
Critical variable costs: CVC = (EY x EP) + S	**6,790,000.00**	**7,312,500.00**

Source: *IAE, 2015; IAE, 2016.*

The amount of achieved contribution margins in the production of tomato in protected area (greenhouse), in the holding A, provides a significant financial reserve for the coverage of fixed costs and making profit.

Similar to the prior production line, although the costs of irrigation (used power generating energy is electrical energy from the public grid) have relatively low share in the structure of variable costs, absolutely expressed (554.00 EUR/ha in 2015, i.e. 378.50 EUR/ha in 2016) leave enough space for finding cheaper and environmentally cleaner alternatives (such as the use of renewable energy).

According to the achieved results in the family agricultural holding B, the *production of tomato in greenhouse* with the use of agro technical measures of irrigation in 2015 and 2016 (*Tables 9-12*), can be noticed:

- In both production years was achieved the positive contribution margin (8,450.26 EUR/ha (in 2015), i.e. 5,895.41 EUR/ha (in 2016). Since technological approach in the production of tomato hasn't been changed, the difference among the achieved contribution margins in amount of 2,554.85 EUR/ha has been a direct consequence of decrease in yield, changes in prices of used inputs and exchange rate of a national currency in relation to euro. As the holding has long-term contracted production of tomato for a known buyer, it wasn't possible to take advantage of the growth in price of final product in the year 2016,
- achieved incomes in the production of tomato are 1.25 times higher than the generated variable costs of production in 2015, i.e. 1.16 times higher than in 2016,
- The costs of engaged labour (36.48%, i.e. 39.15%) dominate in the structure of variable costs in both observed years. The costs of seedlings and equipment also have a high share,
- in the structure of total variable costs, the costs of energy (petrol), necessary for the process of irrigation (drop irrigation) take part with 7.31% (in 2015), i.e. with 9.05% (in 2016). Type and condition of an irrigation pump, number and duration of an irrigation cycle, as well as a price of used energy have affected their amount,
- critical production values, in which the contribution margin equates zero, reflect the following status:
  - Critical price of tomato was amounted 22.34 RSD/kg in 2015, or 24.07 RSD/ha in 2016;
  - Critical yield was amounted 143,391.74 kg/ha in 2015, i.e. 152,460.16 kg/ha in 2016;
  - Critical variable costs were amounted 5,476,875.00 RSD/ha in 2015, i.e. 5,403,850.00 RSD/ha in 2016.

Table 9. *Baseline (tomatoes production in greenhouse)*

Region: Continental - Belgrade (Veliko selo)	Type of soil: Good
Period: Comparison of production results from two 5 months production cycles (2015. and 2016.)	Size of greenhouse: 500 m^2 (10 x50m)
2015.: 1.00 EUR = 120.00 RSD 2016.: 1.00 EUR = 123.00 RSD	Planting density: 2.5 plants per m^2 (12 rows x 50m)

Source: *IAE, 2015; IAE, 2016.*

Table 10. *Contribution margin in tomatoes production in greenhouse*

Element	Quantity	UM	Price per UM (in RSD)	Total RSD/500 m^2	Total EUR/500 m^2	Total EUR/ha
A-1 Incomes – 2015.						
Tomatoes	9,375.00	kg	-	-	-	-
I class (80%)	7,500.00	kg	30.00	225,000.00	1,875.00	-
II class (15%)	1,405.00	kg	25.00	35,125.00	292.70	-
Spoilage (5%)	470.00	kg	-	-	-	-
Subsidies	-	-	-	-	-	-
Total A-1				**260,125.00**	**2,167.70**	**43,354.20**
A-2 Incomes – 2016.						
Tomatoes	9,250.00	kg	-	-	-	-
I class (85%)	7,860.00	kg	30.00	235,800.00	1,917.10	-
II class (10%)	925.00	kg	25.00	23,125.00	188.00	-
Spoilage (5%)	465.00	kg	-	-	-	-
Subsidies	-	-	-	-	-	-
Total A-2				**258,925.00**	**2,105.10**	**42.101,60**
Difference (A-2 – A-1)				**-1,200.00**	**-62.60**	**-1.252,60**
B-1 Variable costs – 2015.						
Total B-1				**209,422.70**	**1,745.20**	**34,903.94**
B-2 Variable costs – 2016.						
Total B-2				**222,593.30**	**1,810.32**	**36,206.19**
Difference (B-2 – B-1)				**13,170.60**	**65.12**	**1,302.25**
I Contribution margin – 2015. (A-1 – B-1)				**50,702.30**	**422.50**	**8,450.26**
II Contribution margin – 2016. (A-2 – B-2)				**36,331.70**	**294.78**	**5,895.41**
Difference (II – I)				**-14,370.60**	**-127.72**	**-2,554.85**

Source: *IAE, 2015; IAE, 2016.*

Table 11. *Structure of variable costs (VC) in tomatoes production in greenhouse*

Element	Total RSD/ha (2015.)	Share in total VC (%)	Total RSD/ha (2016.)	Share in total VC (%)
Seedlings	1,000,000.80	23.87	937,499.80	21.05
Fertilizers	130,728.00	3.12	134,999.90	3.03
Pesticides	197,280.00	4.71	201,000.50	4.51
Packaging material	60,000.00	1.43	61,500.00	1.38
Mechanized operations	123,408.00	2.95	124,498.10	2.80
Equipment	820,080.00	19.58	823,669.50	18.49
Costs of energy (irrigation)	306,000.00	7.31	403,194.00	9.05
Engaged labour	1,527,984.00	36.48	1,742,999.80	39.15
Other costs	22,992.00	0.55	23,999.80	0.54
Variable costs (total)	**4,188,472.80**	**100.00**	**4,453,361.40**	**100.00**

Source*: IAE, 2015; IAE, 2016.*

Table 12. *Critical values in tomatoes production in greenhouse*

Element	RSD(kg)/ha - 2015.	RSD(kg)/ha - 2016.
Expected yield (EY)	187,500.00	185,000.00
Expected price (EP)	29.21	29.21
Subsidies (S)	-	-
Variable costs (VC)	4,188,472.80	4,453,361.40
Critical price: CP = (VC - S) / EY	**22.34**	**24.07**
Critical yield: CY = (VC - S) / EP	**143,391.74**	**152,460.16**
Critical variable costs: CVC = (EY x EP) + S	**5,476,875.00**	**5,403,850.00**

Source: *IAE, 2015; IAE, 2016.*

The realized contribution margins in the production of tomato in greenhouse should be sufficient, in both years, for covering fixed costs and positive business operations. The costs of irrigation (consumed energy – petrol) have, as relatively high share in the structure of variable costs, as well as absolutely high amount (2,550.00 EUR/ha in 2015, i.e. 3,278.00 EUR/ha in 2016). Accordingly, with high probability, a holding could make a higher profit, if it performs an energy transfer towards ecologically and cost-friendly alternative (wind and solar energy).

Presented results in the *production of cabbage in open field*, along with the use of agro-technical measures of irrigation, in the holding B, in 2015 and 2016 (*Tables 13-16*), point out to:

- In both observed years, the holding was realised the positive contribution margin in amount of 6,349.73 EUR/ha in 2015, or 7,493.95 EUR/ha in 2016. The difference of 1,144.22 EUR/ha is primary the consequence of better price of cabbage in 2016;
- Realised incomes in the production of cabbage are 2.65 times (in the year 2015) i.e. 2.75 times (in 2016) higher than the incurred variable costs of production,
- Costs of engaged labour (33.72% in 2015, i.e. 34.59%) dominate in the structure of variable costs. The costs of seedlings are also pretty high,
- costs of energy (diesel fuel), necessary for the process of irrigation (sprinklers), have a significant share in the structure of variable costs (2.25% in 2015, i.e. 7.93% in 2016);
- Critical values of production, the values in which make equal total value and total variable costs, point out to the following results:
  - Critical price amounts 6.04 RSD/kg in 2015, or 7.06 RSD/kg in 2016;

- Critical yield amounts 25,168.50 kg/ha in 2015, i.e. 24,627.70 kg/ha in 2016;
- Critical variable costs amount 1,350,000.00 RSD/ha in 2015, i.e. 1,612,500.00 RSD/ha in 2016.

Table 13. *Baseline (cabbage production in the open field)*

Region: Continental – Belgrade (Veliko selo)	Type of soil: Good
Period: Comparison of production results from two production cycles (2015. and 2016.)	Production area: 80 are (2015.) and 16 are (2016.)
2015.: 1.00 EUR = 120.00 RSD 2016.: 1.00 EUR = 123.00 RSD	Planting density: 60 x 45 cm

Source: IAE, 2015; IAE, 2016.

Table 14. *Contribution margin in cabbage production in the open field*

Element	Quantity	UM	Price per UM (in RSD)	Total RSD/80 are	Total EUR/80 are	Total EUR/ha
A-1 Incomes – 2015.						
Cabbage	60,000.00	kg	-	-	-	-
I class (90%)	54,000.00	kg	18.00	972,000.00	8,100.00	-
Spoilage(10%)	6,000.00	kg	-	-	-	-
Subsidies	-	-	-	-	-	-
Total A-1				**972,000.00**	**8,100.00**	**10,125.00**
B-1 Variable costs – 2015.						
Total B-1				**362,425.20**	**3,020.21**	**3,775.27**
I Contribution margin – 2015. (A-1 – B-1)				**609,574.80**	**5,079.79**	**6,349.73**
Element	**Quantity**	**UM**	**Price per UM (in RSD)**	**Total RSD/16 are**	**Total EUR/16 are**	**Total EUR/ha**
A-2 Incomes – 2016.						
Cabbage	12,000.00	kg	-	-	-	-
I class (90%)	10,800.00	kg	21.50	232,200.00	1,887.80	-
Spoilage(10%)	1,200.00	kg	-	-	-	-
Subsidies	-	-	-	-	-	-
Total A-2				**232,200.00**	**1,887.80**	**11,798.80**
B-1 Variable costs – 2016.						
Total B-2				**84,715.00**	**688.78**	**4,304.85**
II Contribution margin – 2016. (A-2 – B-2)				**147,485.00**	**1,199.02**	**7,493.95**
Difference (A-2 – A-1)						**1,673.80**
Difference (B-2 – B-1)						**529.58**
III Difference (II – I)						**1,144.22**

Source: *IAE, 2015; IAE, 2016.*

Table 15. *Structure of variable costs (VC) in cabbage production in the open field*

Element	Total RSD/ha (2015.)	Share in total VC (%)	Total RSD/ha (2016.)	Share in total VC (%)
Seedlings	131,250.00	28.97	140,625.90	26.56
Fertilizers	65,650.80	14.49	67,188.80	12.69
Pesticides	28,320.00	6.25	29,064.90	5.49
Mechanized operations	62,550.00	13.81	65,288.40	12.33
Costs of energy (irrigation)	10,200.00	2.25	42,004.50	7.93
Engaged labour	152,749.20	33.72	183,134.70	34.59
Other costs	2,312.40	0.51	2,189.40	0.41
Variable costs (total)	**453,032.40**	**100.00**	**529,496.60**	**100.00**

Source: *IAE, 2015; IAE, 2016.*

Table 16. *Critical values in cabbage production in the open field*

Element	RSD(kg)/ha - 2015.	RSD(kg)/ha - 2016.
Expected yield (EY)	75,000.00	75,000.00
Expected price (EP)	18.00	21.50
Subsidies (S)	-	-
Variable costs (VC)	453,032.40	529,496.60
Critical price: CP = (VC - S) / EY	**6.04**	**7.06**
Critical yield: CY = (VC - S) / EP	**25,168.50**	**24,627.70**
Critical variable costs: CVC = (EY x EP) + S	**1,350,000.00**	**1,612,500.00**

Source: *IAE, 2015; IAE, 2016.*

The amount of realized contribution margins in the production of cabbage in the holding B, in both years, should cover the fixed costs and the realization of positive financial result (profit). Costs of energy used during the process of irrigation (diesel fuel), expressed per hectare of production area, differ significantly in the observed years (85.00 EUR/ha in 2015, i.e. 341.50 EUR/ha in 2016), which is predominantly the consequence of a type, power and condition of used generators for running the irrigation system, number and duration of an irrigation cycle, as well as a price of used energy. Potential conversion of used energy by the environmentally preferable alternative (solar and wind energy), would surely reflect to higher profitability of a described production line.

Conclusion

Energy demand of large number of activities within modern, multifunctional agriculture can be satisfied by renewable energy (such as solar and wind energy), which could replace widely used fossil fuels. Goals defined by project

„Socio-economic and ecological aspects of RE application in agricultural production of the Republic of Serbia" are in accordance with the entire actual national legislation regarding promotion and support of increasing use of RE in the sector of agriculture.

Vegetable growing in open space or within a protected area, from the aspect of technological competitiveness, must satisfy basic conditions of profitability and food safety. On the other hand, considering the pressure of climate change in our production conditions, modern vegetable production requires application of agro-technical measures such as irrigation (sprinkler systems and drop irrigation prevail) where there is a general practice to apply irrigation as a basic production measure.

Analysis of field testing results of a mobile robotic solar electrical generator and a mobile wind generator in vegetable production (cabbage and tomato) in open space and within the protected area at agricultural farms in villages Glogonj and Veliko Selo during 2015 and 2016, with simultaneously applied irrigation of crops, showed positive results in the observed vegetable production lines, based on the contribution margin calculation.

It is noticeable that in the structure of variable costs, the costs of irrigation, i.e. the costs of consumed energy (diesel fuel, petrol or electricity) depending on a type, power and condition of power generating unit, frequency and length of a cycle of irrigation and used energy, have relatively low/modest share:

- *For electrical energy* from 0.8% to 1.3%,
- *For petrol* from 7.3% to 9%,
- *For diesel* from 2.3% to 7.9%.

On the other hand, an absolutely expressed value of these costs per hectare of production area under vegetable crops was ranged:

- *For electrical energy* from 379 to 554 EUR;
- *For petrol* from 2,550 to 3,280 EUR;
- *For diesel* from 85 to 364 EUR.

Everything above shown indicates that some farms in certain vegetable production lines must find cheaper (needless dissipation of inputs) and ecologically more acceptable solutions, such as solar energy (mobile robotic solar electric generator) or wind energy (mobile wind generator).

Analysis of the research results indicates that, during moderate irrigation, the mobile robotic solar electric generator (basic or improved types of devices) or mobile wind generator are several times more cost-effective and ecologically very acceptable. Limitation can be the operations autonomy of devices:

- *for basic version of the mobile robotic solar electric generator* (mono-phase device with maximum power of 3 KW) about 2 working hours (with battery discharge till the level of repletion 30%);
- *for improved version of the mobile robotic solar electric generator* (three-phase device with frequent regulator of 4 KW maximum power and stronger batteries) about 4 working hours (with battery discharge till the level of repletion 30-40%);
- *for mobile wind generator* (power of around 1,5 KW) about 4 working hours.

This means that, in all possible cases, in spite of cheap energy, it is possible to irrigate daily up to ¼ hectares (25 are) of production area, after which work of device depends on connecting to the electrical network or by mutual complementing of solar or wind energy devices.

On the other hand, one can assume the following:

a) *Holding disposes with 1 or 2ha of production area under vegetables* (open field and green house) with the possibility of organizing two production cycles of a vegetable culture during one year (spring and summer planting); Average collective costs for all production lines and irrigation systems for one production cycle was about 988 EUR (approximately 1,000 EUR). The Ministry of Agriculture and Environmental Protection gives incentives for agricultural mechanization and equipment in amount of 40% of their purchasing value (50% in marginal regions). Lifetime of a device is minimum 20 years which is guaranteed by the production specification.

b) *For basic version of robotic solar electric generator*, expected price of device for basic package would be about 7,000 EUR (i.e. 4.200 EUR with incentives of 40%). So, it can be reliably said that investment return, through energy savings, could be slightly above two exploitation years (if it would operate on large farms with 2 ha of production areas or in the case of two production cycles of vegetables during one calendar year).

v) *For the improved version of the mobile robotic solar electric generator*, the estimated price of the device would be about 10,000 EUR (i.e. 6,000 EUR with incentives of 40%). So, one can reliably said that investment return of this device type, through energy savings, would be in three years of exploitation (if it would operate on large farms with 2 ha of production areas or in the case of two production cycles of vegetables during one calendar year).

g) *For the mobile wind generator*, the estimated price of device would be about 3,000 EUR (i.e. 1,800 EUR with incentives of 40%). So, it can be

reliably said that investment return of this device, through energy savings, in the best case scenario, would be slightly more than one year of exploitation of the device (if it would operate on large farms with 2 ha of production areas or in the case of two production cycles of vegetables during one calendar year).

d*) Symbiosis of the improved version of the mobile robotic solar electrical generator and the mobile wind generator* is offered as the most advisable solution, with estimated price of the device of 12,600 EUR (i.e. 7,560 EUR with subventions of 40%). So, with high reliability, one can expect investment return, through energy savings, in the best case scenario, for incomplete four years of exploitation of the device (if it would operate on large farms with 2 ha of production areas or in the case of two production cycles of vegetables during one calendar year).

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