ECONOMIC EFFECTS OF NEW TECHNOLOGIES APPLICATION IN VEGETABLE PRODUCTION[1]

Jonel Subić[2], Marko Jeločnik[3]

Abstract

Strengthening the competitiveness of national agriculture, imposes the need to increase the production of quality and safe food. Because of this, one of the basic tasks of farmer's education should be the advancement of knowledge in the field of new technologies application. Adapted to Serbian agro ecological conditions, new technologies are primarily applied in order to obtain higher quality and safe food, food whose production is socially acceptable, economically viable, and without any negative impact on the environment. Research described in paper was primarily focused on the economic analysis (cost-effectiveness) of the new technologies application (smart sensor networks, mobile robotized solar power generator) in vegetable production. Consequently, analysis was based on experimental measurements, in which were done parallel testing of energy efficiency and economic cost-effectiveness of use of four different pumping systems connected to different irrigation systems: electric pumps connected to the public electrical grid; pumps with gasoline engine; pumps with diesel engine; and electric pumps powered by solar power generator. The experiment was carried out on experimental plots under certain vegetable crops (cauliflower, tomatoes and lettuce) that were produced in the two production systems, on the open field and within the protected area (greenhouse), involving the use of irrigation (drip-drop and sprinkler system). Experimental plots are located in village Glogonj - Upper Danube region and village Veliko Selo - Central Danube region. After detailed analysis of results obtained within the one production cycle in vegetable crops production (analysis was done by use of analytical calculations based on variable costs), certain conclusions indicating economic justification of

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applied new technologies (mobile robotized solar power generator) have been made. Achieved economic effects are reflected through the reduction of fuel spent for irrigation (i.e., variable costs in cauliflower production were decreased for 486 EUR/ha; in tomato production for 554 EUR/ha; or in lettuce production for 340 EUR/ha).

Key words: *robot system, agriculture, economic effects, new technologies, vegetable production.*

Introduction

Stability and quality of yield in plant production lines can be significantly jeopardized under the impact of climatic changes, without wider use of agro-technical measure of irrigation. On the other hand, it is expected from the implementation of irrigation system to be adjusted with the costs and energy efficiency requirements, as well as the expressed orientation toward the environment protection.

Power-generating part of the irrigation system has been mostly relied on the consumption of fossil fuels (petrol and diesel) or to electric power supply from a public electric power grid. As a branch of strategic significance for the sustainable development of national economy, agriculture represents a great consumer of fossil fuels, which exploitation significantly degrades soil and water, while combustion releases gases with greenhouse effects. Of course, prices of agricultural products are highly dependable and sensitive to oscillations of fuel prices, before all, of fossil origin.

According to mentioned, the provision of renewable energy sources, which require minimum engagement of limited land and water resources and do not disturb their ecological status, becomes an important issue for future, not only domestic but also the world food production.

Scientific-research work has confirmed the possibilities of efficient replacement of energy from fossil fuels with the energy from renewable resources, primarily from solar and wind energy. It can be used in numerous activities which are conducted in contemporary, multifunctional agriculture, such are: starting of irrigation pumps, drying of cereals, oilseeds and fruits within the silos or dryers, in the production of artificial fertilizers and pesticides, in greenhouse production and fishery, and especially in organic production, cattle breeding organized on pasture and in agro-eco and eco-organic tourism on holdings in areas of high natural value and with underdeveloped energy infrastructure.

The costs of energy within the structure of total irrigation costs are a significant item, while the use of fossil fuels or the process of electrical energy production, most often directly or indirectly jeopardize environment. In accordance with the global recommendations, accepted by a national law and policy maker, in many strategic documents and legal acts is potentiated a wider application of renewable energy sources. Ultimately, in closer period set goals should lead to a share of renewable energy sources in final consumption of energy at the level of 20%.

In accordance with previously mentioned, science has been given a task to give its full attention in solving the issues of new technologies development regarding the use of renewable energy sources and pure technologies with the zero emission. Direct contribution of national science, by previously expressed global pretensions, reflects in the development of a prototype of mobile robotized solar electro-generator.

At the beginning of the 2015, a mobile robotized solar electro-generator was developed at the institute "Mihajlo Pupin" from Belgrade, the leading national research institution from the field of information-communication technologies (Stevanović et al., 2013). The mobile robotized solar electro-generator is an energy efficient ecological device for the production of electrical energy, by using of the sun light energy (Picture 1.).

Picture 1. ***Mobile robotized solar electro-generator***

Source: Author's archive.

This autonomous device, which doesn't connect to the electrical network and doesn't require any building or energy infrastructure (*stand-alone*), is primarily intended for smaller and medium energy consumers.

This is a new ecological product, unique on the Serbian and surrounding countries market. The product has a general purpose, but it is predominantly projected in order to improve agricultural production, regarding that it provides an intensive but economical irrigation of crops, without noise and pollution of environment. This device is also main nod of smart sensor network for collecting and process of data about soil conditions, soil moisture, soil and air temperature, wind speed at observed area, etc. All of this parameters could be included within the system for optimized irrigation at certain surface depending to soil conditions and short term weather forecast for observed area (Subić et al., 2016).

Main benefits of mobile robotic solar electric generator, which is a subject of present research analysis, in compare to power generator used in conventional irrigation system are as follows:

- Mobile and portable device, suitable for use on any ground;
- There is no requirement for special infrastructure, as well as for preparing the ground for the installation;
- Independent in operation and not connected to the public electrical network;
- Period of autonomy in work lasts for more hours while simultaneous recharging by use of solar energy;
- Easy to use (users friendly), does not require special training or education;
- Silent in operation and without negative impact on the environment;
- Highly automated device, which has the option of remote control;
- Easy and inexpensive to maintain;
- Working life of the device is more than 20 years, while the battery life is 1,000 to 5,000 cycles of charging (depending of level of battery discharging, from 0 to 60% of the full state).

Summarizing all previously presented, research in paper was directed to an analysis of solar energy profitability (use of mobile robotized solar electro-generator) in agriculture. In other words, the research of authors was focused on the assessment of economic effectiveness of new technology application in plant production (*vegetable growing*).

The analysis is based on experimental measuring, to which energy efficiency and economic profitability of using of four different pumping stations of the same power connected to the irrigation system were parallel tested:

- Electric pump connected to the city electro-network;
- Pump with gasoline engine;
- Pump with diesel engine;
- Electrical pump powered by the solar electro-generator.

The experiment was conducted on experimental plots under the certain vegetable crops (cauliflower, tomato and lettuce) in the production system in open field and within the protected area (*greenhouse*), which implies the application of irrigation.

Experimental plots are located at two selected locations:

- In the village Glogonj (at the territory of the Pančevo city, within the wider area of Upper Danube Zone);
- In the village Veliko Selo (at the territory of the Belgrade city, within the narrower area of Central Danube Zone).

All experimental measuring on specified locations was considered the identical project and production conditions.

Vegetable production most often requires a high level of intensity and technical equipment, use of organic and mineral fertilizers, plant care and protection, as well as certain level of attention in the process of harvesting, transportation and storing of fresh fruits. Contemporary vegetable production also considers the application of irrigation, since it provides the necessary conditions for plant growth and development, achievement of high yields, as well as economic viability of investment in other agricultural inputs (Svendsen, Turral, 2007). On the other hand, tendency for higher profitability in some cases led to neglecting of principle of food safety, and in relation to mentioned one of problems in vegetable production in Serbia is the excessive use and disrespect of the withdrawal period of used pesticides (Subić, Jeločnik, 2013).

Material and working methodology

Vegetable production is an important segment of agricultural production, where according to complexity of the applied technology and agro-technical solutions, this production has a relatively big impact on development of national agro-complex.

During period from September to October 2015, field researches were carried out on locality of villages of Glogonj and Veliko Selo, at selected family holdings predominantly oriented to the vegetable production. Mentioned researches, in addition to testing the functioning of mobile robotic solar electro generator, included development of analytical calculations based on variable costs for those vegetable varieties (in this case cauliflower, tomato and lettuce) for which production (within the activities of irrigation), among other things, the solar generator was tested.

Observing the single agricultural holding, for each production it does, it is necessary to create a individual calculation of production value and realized costs, in order to isolate those lines that carry a higher level of profitability. Therefore, calculative framework should provide simple, clear and easy applicable model for analyses of different types of plant and livestock production, which will enable comparison of achieved production results (Jeločnik et al., 2015).

Due to the relative methodological simplification and wideness of practical application, in practice of developed economies usually is used analytical calculations based on variable costs (contribution margin), as analytical base of the management of agricultural holding/enterprises, according to which they can efficiently to manage a costs, and deliver more correct business decisions. Mentioned calculations are particularly suitable for calculating costs on family holdings, which do not have bookkeeping, and therefore does not have all necessary data for development of analytical calculations of total costs (full cost price of the product), (Vasiljević, Subić, 2010/b).

In other words, in conditions of farm orientation to plant production, its complexity assumes analytical tool that would facilitate the current economic analysis of the present state of production at the farm (development of calculations with the elements of production value and costs), or simple analysis of the sustainability of adopted production technology and achieved production results (Subić et al., 2015).

Development of analytical calculation, based on variable costs, starts by determination of the market value of achieved production, which presents market prices of obtained products multiplied by their quantity. Then, by this value are deducted the variable costs of obtained products production.

Starting of new production cycle requires procurement of the necessary production assets, such as: seeds and seedlings, fertilizers, pesticides, energents (fuel) and lubricants, services of agricultural mechanization, labour (family labour and/or engaged workforce), etc. The costs of acquiring and use of almost all mentioned assets have the character of variable costs in agricultural production. Depending on working organization at the holding, labour costs can be observed as fixed or variable cost (included or excluded in a calculative procedure).

The final result of analytical calculations based on variable costs is contribution margin or gross financial result. It is defined as the difference between total production value (the value of the main product plus the value of by-products and subsidies[4]) and the proportional variable costs (Vasiljević, Subić, 2010/a).

Contribution margin could be presented as:

CM = PV – VC, where PV = (q x p) + s

Symbols meaning:

CM - Contribution margin;

PV - Totally achieved production value;

VC - Totally achieved variable costs;

q - Quantity of product per unit of production area;

p - Price of product per unit of measure;

p - Subsidies per unit of production area.

Contribution margin provides indications to the holder of a family agricultural holding (manager of the agricultural enterprises) how much, after covering of variable costs, financial assets remains for fixed costs covering, and achieving of positive financial result (profit). It can be an extremely important indicator in determination of optimal structure of production (using linear programming), or in determination of business risks (Subić et al., 2010/a).

Principally, in vegetable production, calculations based on variable costs allow direct comparison of the financial success of two different lines (or phases) of vegetable production with the same fixed costs, as well as a comparison of two or more different intensities of the same line or phase of vegetable production.

In the vegetable production, depending on the used land area, unit of measure can be adjusted to each entity individually. The obtained result (contribution margin), for each line of vegetable production, is multiplied by the number of hectares - ha (in case of production in the open field), or by the number of square meters - m2 (in case of production within the greenhouse):

TCM = CM x NMU

Where:

TCM - Total contribution margin;

[4] Incentives are usually referred to subsidies or premiums.

CM - Contribution margin;

NMU - Number of measure units (ha or m^2).

After summing of all contribution margins, as indicators of success of certain lines (phases) of production, can be obtained overall contribution margin for vegetable production organized in some agricultural enterprises (family holding). After deduction of total fixed costs from obtained value (costs of production capacities and various overheads) total profit (or loss) of entire vegetable production realized in observed entity in previously determined time period will be gained. Of course, in the case of allocation of fixed costs to certain lines (or phases) of production, mentioned calculation could be in function of obtaining of full cost price of certain vegetable products.

This way presentation of the obtained results, provides a quick and easy overview of business of agricultural holding in one production year (cycle), as well as the calculation of expected economic results in case of changing in production volume, or switching from one to another production (Subić et al., 2010/b).

In assessing the results of crop production, inability to predict future events (primarily incomes and expenses) significantly influence to investment viability, in other words reduce the real possibilities of management in the process of decision making. Accordingly, during the decision making, manager is facing a very complex problem which brings uncertainty, as well as in front of complex task to even slightly reduce the risk of potentially bad decision (Subić, 2010).

In addition to previously mentioned, the assessment of production results of crop production lines under uncertainty could be done by use of different methods and techniques. One of analytical methods is the determination of critical price, critical yield and critical variable costs. These indicators reflect the critical values of production under which the contribution margin (gross financial result) equates to zero (Nastić et al., 2014).

Mentioned indicators could be presented with next formulas:

Critical price: $CP = (VC - S) / EY$

Critical yield: $CY = (VC - S) / EP$

Critical variable costs: $CVC = (EY \times EP) + S$

Meaning of symbols is:

- Expected yield (EY);

- Expected price (EP);
- Subsidies (S);
- Variable costs (VC).

As was previously mentioned, the experiment was considered field research, which was conducted during the September and October 2015. Besides the testing of mobile robotic solar electric generator in real conditions, research has implied the collection of data throughout the in-depth interview of members of selected family holdings predominantly oriented to the vegetable production.

Each surveyed household is specific by the application, to some extent, different production technology, different approach to the procurement of the necessary production materials and sale of produced vegetables. Selected holdings (including production areas) are located at the territory of the village Glogonj (2 holdings) and Veliko Selo (1 holdings). Analytical calculations were made only for the vegetable crops in which production cycle (within the application of irrigation) was tested solar electro generator. Observed vegetable crops were grown in the open field (cauliflower and lettuce), and in protected area – greenhouse (tomato).

For the purposes of this study, all calculations are done on the basis of the production value and variable costs, realized at the utilized agricultural (production) area at observed holdings. Then, in order to facilitate the comparison of achieved results and adopted production technology, all values are brought down to the area of 1 ha. In order to provide a wider comparison of achieved value indicators, all variable costs and production values are expressed both in national currency (RSD) and official currency of the European Union (EUR).

From the aspect of methodology, calculation principle of certain items within the calculation based on variable costs in crop production is identical, unless there are specific items of the production value or variable costs in certain lines of production.

Used model of calculation, in the production of selected vegetable crops, is based on the presentation of all indicators throughout several separate tables and charts. Previously all data and indicators are logically tested, or analysed by use of standard mathematical-statistical methods. The reason for such a presentation was found in accentuation of detailed calculation procedure and structure of contribution margin calculation based on variable costs.

Intention was primarily found in marking of the costs of different energy sources used within the process of irrigation during the production of selected vegetable crops, which can be substituted and reduced by use of solar energy. In other words, there was a need for pointing out to the agricultural producers the size of energy costs and their share within the structure of total variable costs in the vegetable production.

According to overall importance of selected vegetable crops, closeness of the market, tradition of growing, adopted technological approach, following research activities were conducted:

- Analytical calculations based on variable costs (contribution margin) were done;
- Detailed structure of total variable costs were determined;
- Critical price, critical yield and critical variable costs for each line of vegetable production were determined (evaluation of production results in conditions of uncertainty).

Theoretical and material basis were taken from the available scientific and technical literature focused on the researched issue, as well as from in-depth interviews with the members of selected family agricultural holdings. Most of obtained data is directly related to the current production year (2015), while some are producers' estimations or scientifically verified standard for some line of vegetable production.

Research results

Vegetable production (in this case: cauliflower, tomato and lettuce) is important segment of agriculture, as a meter of fact, a significant factor of national agro-economy competitiveness.

Considering the fact that a numerous of family holdings are dealing with vegetable production, the results of research can be of great importance, not only for members of those family holdings, but also for managers of agricultural enterprises, which production structure include vegetables. Those reasons are enough for choosing of calculations based on variable costs for mentioned crops, in order to see the influence of costs of energy related to irrigation on the economic results of production.

Testing of mobile robotic solar electric generator was carried out on fields under vegetable crops cultivated in production system which includes irrigation, considering that this production system significantly affects the stability and yield (vegetable crops require significant amount of water). On the other hand, the assumption is that incomes from the valorisation of cultivated vegetables cover all production costs (both variable and fixed), and provide enough financial assets for return of the investment in purchase/implementation of irrigation system.

According to methodology used, the irrigation costs have the character of variable costs, and such as are related to:

- Covering the costs of fuel and lubricants (i.e. covering the costs of energetics and variable costs of irrigation system);
- Paying of liabilities related to irrigation (i.e. reimbursement for water used for irrigation, reimbursement for water facilities used as a part of irrigation systems, fees for usage of regional irrigation systems and other water facilities, etc.).

In this study, mitigating circumstance is the fact that selected holdings have their own wells (water intakes). From previous experience, expectations are that the contribution of irrigation is that growth of incomes at holding exceed the growth of variable costs caused by irrigation use, as that cash outflows for the implementation of mentioned agro-technical measure (by which is compensated natural deficit of required amount of water of plants) are not significantly present within the structure of total variable costs.

1) Calculation of cauliflower production in open field

Table 1. ***Baselines***

Territory: Upper Danube Region (Glogonj)	Type of soil: good
Period: 1 production cycle (2015)	Area of production plot: 0,14 ha
1,00 EUR = 120,00 RSD	Space between plants: 60x50 cm

Source: *Group of authors (2015): Techno – economic aspects of use of renewable energy sources and mobile robotized solar electro-generators in agriculture, Study, IAE Belgrade, IMP Belgrade and PSSS Padinska Skela, Belgrade.*

Table 2. ***Contribution margin in cauliflower production in open field***

Element	Quantity	UM	Price per UM (in RSD)	Total RSD/ 0,14 ha	Total EUR/ 0,14 ha	Total EUR/ha
Incomes: A						
Cauliflower	5.875,00	kg	-	-	-	-
I class (95%)	5.580,00	kg	45,00	251.100,00	2.092,50	-
Spoilage (5%)	295,00	kg	-	-	-	-
Subsidies	14,00	ar	120,00	1.680,00	14,00	-
Total				**252.780,00**	**2.106,50**	**15.046,43**
Variable costs: B						

Seedlings	4.700,00	pcs	7,00	32.900,00	274,17	1.958,36
Fertilizers	-	-	-	16.372,50	136,44	974,57
Pesticides	-	-	-	7.505,40	62,54	446,71
Land tenure	-	-	-	-	-	-
Insurance	-	-	-	-	-	-
Ploughing (30 cm)	14,00	ar	90,00	1.260,00	10,50	75,00
Dispersal of manure	14,00	ar	112,5	1.575,00	13,12	93,71
Dispersal of mineral fertilizers	14,00	ar	15,00	210,00	1,75	12,50
Disking	14,00	ar	23,00	322,00	2,68	19,14
Pre-sowing treatment	14,00	ar	24,00	336,00	2,80	20,00
Planting (man.)	15,00	hour	200,00	3.000,00	25,00	178,57
Pesticide treatment (mec.)	5,00	treatment	350,00	1.750,00	14,58	104,14
Pesticide treatment and fertilizing (man.)	3,00	hour	200,00	600,00	5,00	35,71
Corrective hilling (mec.)	14,00	ar	17,00	238,00	1,98	14,14
Corrective hilling (man.)	8,00	hour	200,00	1.600,00	13,33	95,24
Harvesting (man.) with packaging, measuring, loading to lorry	72,00	hour	200,00	14.400,00	120,00	857,14
Packaging (carton box 20 kg)	300,00	pcs	50,00	15.000,00	125,00	892,86
Transportation	20,00	tour	600,00	12.000,00	100,00	714,29
Costs of stand tenure	-	-	-	7.100,00	59,17	422,64
Irrigation equipment	-	-	-	-	-	-
Preparation and presence of worker during irrigation	50,00	hour	200,00	10.000,00	83,33	595,21
Costs of water (irrigation)	-	-	-	-	-	-
Costs of fuel (diesel) for irrigation	60,00	l	136,00	8.160,00	68,00	485,71
Other costs	-	-	-	750,00	6,25	44,64
Total				**135.078,90**	**1.125,64**	**8.040,28**
Contribution margin: C = (A-B)				**117.701,10**	**980,86**	**7.006,15**

Source: *Group of authors (2015): Techno – economic aspects of use of renewable energy sources and mobile robotized solar electro-generators in agriculture, Study, IAE Belgrade, IMP Belgrade and PSSS Padinska Skela, Belgrade.*

Note: Value of mechanized operation was determined according to prices given by guide of Cooperative Union of AP Vojvodina, 2013.

Table 3. ***Structure of variable costs in cauliflower production in open field***

Element	Total RSD/ha	Total EUR/ha	Share in total variable costs (%)
Seedlings	235.003,20	1.958,36	24,36
Fertilizers	116.948,40	974,57	12,12
Pesticides	53.605,20	446,71	5,55
Carton boxes	107.143,20	892,86	11,10
Mechanized operations	126.350,40	1.052,92	13,10
Costs of energy (irrigation)	58.285,20	485,71	6,04
Engaged labour	211.424,40	1.761,87	21,91
Other costs	56.073,60	467,28	5,82
Variable costs (total)	**964.833,60**	**8.040,28**	**100,00**

Source: *Group of authors (2015): Techno – economic aspects of use of renewable energy sources and mobile robotized solar electro-generators in agriculture, Study, IAE Belgrade, IMP Belgrade and PSSS Padinska Skela, Belgrade.*

Table 4. ***Critical values of production***

Description	RSD(kg)/ha	EUR(kg)/ha
Expected yield (EY)	41.965,00	41.965,00
Expected price (EP)	45,00	0,375
Subsidies (S)	12.000,00	100,00
Variable costs (VC)	964.833,60	8.040,28
Critical price: CP = (VC - S) / EY	**22,75**	**0,19**
Critical yield: CY = (VC - S) / EP	**21.174,00**	**21.174,00**
Critical variable costs: CVC = (EY x EP) + S	**1.900.425,00**	**15.836,87**

Source: *Group of authors (2015): Techno – economic aspects of use of renewable energy sources and mobile robotized solar electro-generators in agriculture, Study, IAE Belgrade, IMP Belgrade and PSSS Padinska Skela, Belgrade.*

Gained results in the production of cauliflower in the open field with the use of irrigation (Tables 1-4.) suggest the following:

- In presented case of cauliflower production on observed holding, positive contribution margin was achieved (around 7.006,15 EUR/ha);
- Achieved incomes in cauliflower production are almost doubled in compare to generated variable costs of production;
- In the structure of variable costs, the cost of fuel (diesel) required for the process of irrigation, have a relatively modest share (i.e., around 6,04%);
- In the structure of variable costs dominate the costs of seedlings and engaged labour (with the share of 24,36%, or 21,91%);
- Critical values of production (values when contribution margin equates to zero) have the following values:
    - Critical price is 0,19 EUR/kg;
    - Critical yield is 21.174,00 kg/ha;

- Critical variable costs are 15.836,87 EUR/ha.

From the given case of achieved contribution margin in the production of cauliflower at the observed holding, it can be state with considerable degree of certainty that the contribution margin leaves enough space that after covering of all variable costs, the remaining assets for covering of fixed costs and achieving of positive financial result.

Although within the structure of variable costs, the cost of irrigation (in this case costs of energy - diesel) have relatively modest value, absolutely expressed (485,71 EUR/ha) it points to the possibility of their reduction or conversion of used energy source with cheaper and environmentally more desirable solution (solar energy).

2) Calculation of tomato production in greenhouse

Table 5. ***Baselines***

Territory: Upper Danube Region (Glogonj)	Type of soil: good
Period: 1 production cycle, 5 months (during 2015)	Size of greenhouse: 200 m^2
1,00 EUR = 120,00 RSD	Planting density: 2,5 plants per m^2 (4 rows x 35 m)

Source: *Group of authors (2015): Techno – economic aspects of use of renewable energy sources and mobile robotized solar electro-generators in agriculture, Study, IAE Belgrade, IMP Belgrade and PSSS Padinska Skela, Belgrade.*

Table 6. ***Contribution margin in tomato 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: Incomes						
Tomato	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				**129.000,00**	**1.075,00**	**53.750,00**
B: Variable costs						
Seedlings	500,00	pcs	35,00	17.500,00	145,83	7.291,50
Fertilizers	-	-	-	16.900,00	140,83	7.041,50
Pesticides	-	-	-	4.655,20	38,80	1.940,00
Dispersal of manure	12,00	hour	200,00	2.400,00	20,00	1.000,00
Strings	2,00	hank	500,00	1.000,00	8,34	417,00
Mulch foil (stripes)	140,00	m	8,00	1.120,00	9,33	466,50
Foil (UV, anti-drop, anti-insect)	1/4	set	60.000,00	15.000,00	125,00	6.250,00
Shading net (3,60x50 m)	1/4	pcs	4.500,00	1.125,00	9,37	468,50
Packaging (used wooden box, 10 kg)	400,00	pcs	15,00	6.000,00	50,00	2.500,00

Stripe drips	140,00	m	5,20	728,00	6,07	303,50
Planting	6,00	hour	200,00	1.200,00	10,00	500,00
Binding	8,00	hour	200,00	1.600,00	13,34	667,00
Costs of laterals nipping	6,00	hour	200,00	1.200,00	10,00	500,00
Pesticide treatment	8,00	hour	200,00	1.600,00	13,33	666,50
Soil milling by moto cultivator	2,00	hour	500,00	1.000,00	8,34	417,00
Fruits picking, sorting and packaging	72,00	hour	200,00	14.400,00	120,00	6.000,00
Transportation	8,00	tour	1.000,00	8.000,00	66,67	3.333,50
Costs of stand tenure	-	-	-	7.100,00	59,17	2.958,50
Insurance of greenhouse	-	-	-	-	-	-
Costs of greenhouse heating	-	-	-	-	-	-
Costs of water (irrigation)	-	-	-	-	-	-
Costs of electric power (irrigation)	180,00	KWh	7,386	1.329,48	11,08	554,00
Other costs	-	-	-	750,00	6,25	312,50
Total				**104.607,68**	**871,75**	**43.587,50**
Contribution margin: C = (A-B)				**24.392,32**	**203,25**	**10.162,50**

Source: *Group of authors (2015): Techno – economic aspects of use of renewable energy sources and mobile robotized solar electro-generators in agriculture, Study, IAE Belgrade, IMP Belgrade and PSSS Padinska Skela, Belgrade.*

Note: Value of mechanized operation was determined according to prices given by guide of Cooperative Union of AP Vojvodina, 2013.

Table 7. *Structure of variable costs in tomato production in greenhouse*

Element	Total RSD/ha	Total EUR/ha	Share in total variable costs (%)
Seedlings	874.980,00	7.291,50	16,73
Fertilizers	844.980,00	7.041,50	16,15
Pesticides	232.800,00	1.940,00	4,45
Wooden boxes	300.000,00	2.500,00	5,73
Mechanized operations	400.020,00	3.333,50	7,65
Equipment	948.660,00	7.905,50	18,14
Costs of energy (irrigation)	66.480,00	554,00	1,27
Engaged labour	1.170.060,00	9.750,50	22,37
Other costs	392.520,00	3.271,00	7,51
Variable costs (total)	**5.230.500,00**	**43.587,50**	**100,00**

Source: *Group of authors (2015): Techno – economic aspects of use of renewable energy sources and mobile robotized solar electro-generators in agriculture, Study, IAE Belgrade, IMP Belgrade and PSSS Padinska Skela, Belgrade.*

Table 8. ***Critical values of production***

Description	RSD (kg)/ha	EUR (kg)/ha
Expected yield (EY)	200.000,00	200.000,00
Expected price (EP)[1]	33,95	0,28
Subsidies (S)	-	-
Variable costs (VC)	5.230.500,00	43.587,50
Critical price: CP = (VC - S) / EY	**26,15**	**0,22**
Critical yield: CY = (VC - S) / EP	**154.064,80**	**154.064,80**
Critical variable costs: CVC = (EY x EP) + S	**6.790.000,00**	**56.583,33**

Note: [1] as holdings usually class the tomato, so expected price represents average price of sold kilogram of product.

Source: *Group of authors (2015): Techno – economic aspects of use of renewable energy sources and mobile robotized solar electro-generators in agriculture, Study, IAE Belgrade, IMP Belgrade and PSSS Padinska Skela, Belgrade.*

Achieved results in tomato production in greenhouse by use of irrigation (Table 5-8.), lead to next conclusions:

- In presented production line at observed holding, positive contribution margin was achieved (around 10.162,50 EUR/ha);
- Achieved incomes in tomato production are for 1,2 times higher than generated variable costs of production;
- Costs of energy (electric power) required for the process of irrigation have a relatively small share (i.e., around 1,27%) within the structure of total variable costs;
- In the structure of variable costs dominate the costs of engaged labour (with the share of 22,37%);
- Critical values of production (values when contribution margin equates to zero) have the following values:
  - Critical price is 0,22 EUR/kg;
  - Critical yield is 154.064,80 kg/ha;
  - Critical variable costs are 56.583,33 EUR/ha.

Cover margin obtained in the production of tomatoes in greenhouse at the observed holding should be sufficient to cover all fixed costs and gain the profit. Similar to the previous case, although the costs of irrigation (energy source is electricity) have a relatively low share in the structure of variable costs, in absolute amount (554,00 EUR/ha) leave enough space for finding of cheaper alternatives.

3) Calculation of lettuce production in open field

Table 9. ***Baselines***

Territory: Continental – Belgrade Region	Type of soil: good
Period: 1 production cycle from seedlings, 45 days (during 2015), lettuce Kristal	Production are: 5ar/0,05 ha
1,00 EUR = 120,00 RSD	Planting density: 35x25 cm

Source: *Group of authors (2015): Techno – economic aspects of use of renewable energy sources and mobile robotized solar electro-generators in agriculture, Study, IAE Belgrade, IMP Belgrade and PSSS Padinska Skela, Belgrade.*

Table 10. ***Contribution margin in lettuce production in open field***

Element	**Quantity**	**UM**	**Price per UM (in RSD)**	**Total RSD/5 ar**	**Total EUR/5ar**	**Total EUR/ha**
A: Incomes						
Lettuce	10.000,00	pcs	-	-	-	-
I class (90%)	9.000,00	pcs	22,00	198,000,00	1.650,00	-
II class (8%)	800,00	pcs	17,00	13.600,00	113,33	-
Spoilage (2%)	200,00	pcs	-	-	-	-
Subsidies	-	-	-	-	-	-
Total				**211.600,00**	**1.763,33**	**35.266,60**
B: Variable costs						
Seedlings	10.000,00	pcs	7,50	75.000,00	625,00	12.500,00
Fertilizers	-	-	-	4.491,00	37,42	748,40
Pesticides	-	-	-	4.493,60	37,45	749,00
Fertilizers dispersal (man)	2,00	hour	200,00	400,00	3,33	66,60
Mulch foil (stripes)	-	-	-	-	-	-
Packaging (carton box)	500,00	pcs	35,00	17.500,00	145,83	2.916,60
Irrigation equipment	-	-	-	-	-	-
Planting	70,00	hour	200,00	14.000,00	116,67	2.333,40
Pesticide treatment (man)	8,00	hour	200,00	1.600,00	13,33	266,60
Ploughing (25 cm)	5,00	ar	80,00	400,00	3,33	66,60
Tractor milling (15 cm)	5,00	ar	54,00	270,00	2,25	45,00
Soil milling by moto cultivator	1,00	hour	500,00	500,00	4,17	83,40
Harvesting and lettuce packaging	150,00	hour	200,00	30.000,00	250,00	5.000,00
Transportation	30,00	tour	150,00	4.500,00	37,50	750,00
Costs of water (irrigation)	-	-	-	-	-	-
Costs of fuel (gasoline) for irrigation	15,00	l	136,00	2.040,00	17,00	340,00
Other costs (fees, etc.)	-	-	-	350,00	2,92	58,40
Total				**155.544,60**	**1.296,20**	**25.924,00**
Contribution margin: C = (A-B)				**56.055,40**	**467,13**	**9.342,60**

Source: *Group of authors (2015): Techno – economic aspects of use of renewable energy sources and mobile robotized solar electro-generators in agriculture, Study, IAE Belgrade, IMP Belgrade and PSSS Padinska Skela, Belgrade.*

Note: Value of mechanized operation was determined according to prices given by guide of Cooperative Union of AP Vojvodina, 2013.

Table 11. ***Structure of variable costs in lettuce production in open field***

Element	Total RSD/ha	Total EUR/ha	Share in total variable costs (%)
Seedlings	1.500.000,00	12.500,00	48,22
Fertilizers	89.808,00	748,40	2,89
Pesticides	89.880,00	749,00	2,90
Carton boxes	349.992,00	2.916,60	11,25
Mechanized operations	113.400	945,00	3,64
Costs of energy (irrigation)	40.800,00	340,00	1,31
Engaged labour	919.992,00	7.666,60	29,57
Other costs	7.008,00	58,40	0,22
Variable costs (total)	**3.110.880,00**	**25.924,00**	**100,00**

Source: Group of authors (2015): Techno – economic aspects of use of renewable energy sources and mobile robotized solar electro-generators in agriculture, Study, IAE Belgrade, IMP Belgrade and PSSS Padinska Skela, Belgrade.

Table 12. ***Critical values of production***

Description	RSD (pcs)/ha	EUR (pcs)/ha
Expected yield (EY)	200.000,00	200.000,00
Expected price (EP)[1]	21,59	0,18
Subsidies (S)	-	-
Variable costs (VC)	3.110.880,00	25.924,00
Critical price: CP = (VC - S) / EY	**15,55**	**0,13**
Critical yield: CY = (VC - S) / EP	**144.088,93**	**144.088,93**
Critical variable costs: CVC = (EY x EP) + S	**4.318.000,00**	**36.000,00**

Note: [1] as lettuce is classed at the holding, expected price represents average price of sold head of lettuce.

Source: Group of authors (2015): Techno – economic aspects of use of renewable energy sources and mobile robotized solar electro-generators in agriculture, Study, IAE Belgrade, IMP Belgrade and PSSS Padinska Skela, Belgrade.

Achieved results in lettuce production in open field by use of irrigation (Table 10-12.), lead to next conclusions:

- In presented production line at observed holding, positive contribution margin was achieved (around 9.342,60 EUR/ha);
- Achieved incomes in lettuce production in open field are for 1,36 times higher than generated variable costs of production;
- Costs of energy (gasoline) required for the process of irrigation have a relatively small share (i.e., around 1,31%) within the structure of total variable costs;
- In the structure of variable costs dominate the costs of seedlings (with the share of 48,22%);
- Critical values of production (values when contribution margin equates to zero) have the following values:

- Critical price is 0,13 EUR/kg;
- Critical yield is 144.088,93 kg/ha;
- Critical variable costs are 36.000,00 EUR/ha.

According to presented contribution margin achieved in the production of lettuce in open field at the observed holding, it can be said with considerable degree of certainty that it leaves enough space for covering of fixed costs and profit gaining. Although within the structure of variable costs, the costs of irrigation (costs of spent gasoline) have a relatively small value, absolutely expressed (340,00 EUR/ha) point out to the issue of their possible reduction or substitution of used energy into the cheaper and environmentally more friendly solution (solar energy).

Conclusion

The results of field testing of mobile solar electric generator in vegetable production (cauliflower, tomatoes and lettuce) in open field and greenhouse, with usage of irrigation system on selected farms in the village Glogonj and Veliko Selo, are created by analytic calculations based on variable costs.

The analysis showed that all observed production lines achieved positive contribution margin, giving the conclusion that all farms over mastered technological process of vegetable production. In the structure of variable costs, by individual vegetable production lines, the costs of seedlings or labour costs are dominant. On the other hand, the irrigations costs (used petrol, diesel or electricity for activity of irrigation) were relatively low (varying in the range of 1,27% to 6,04%). However, the value of these costs expressed in absolute value per hectare of production area, was in range from 340,00 up to 554,00 EUR/ha. These results impose the need that some of holdings for certain vegetable production lines, have to find cheaper and from aspect of environment much cleaner energy alternatives. Application of solar energy, by using mobile solar electro-generators, is identified as ideal solutions for this issue.

Potential limit to the system is recognized in the fact that, despite the cheap energy, smart sensor networks and solar irrigation system, per one day it can be irrigated up to the half of hectare for three working hours. After that, system must be left to the charge, either by using of solar energy, or by connection to the public electrical network. Therefore, the daily capacity of the irrigation by tested device is maximum half of hectare.

On the other hand, next can be assumed: expected price of device in the base package of equipment could be range around 7.000,00 EUR; Ministry of Agriculture and Environmental Protection of the Republic of Serbia would be subsidized 40% of the device value (50% in marginal areas); Vegetable Association/family holding disposes with three hectares of production area under vegetables, whereby during one calendar year may be carried out two production cycles of certain vegetable crops (spring and summer planting); the average cost of energy used for irrigation of vegetable crops during one production cycle were around 459,90 EUR/ha.

According to presented, with a great degree of certainty can be expected that the period of return of assets invested in mentioned device, throughout the savings in costs of energy, will be under the three years of device exploitation.

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