CONSIDERATIONS ON ENERGY EFFICIENCY OF GREENHOUSES FOR VEGETABLE PRODUCTION

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REZUMAT. Lucrarea s-a născut ca necesitate de reducere a costurilor de exploatare a unei sere şi în acelaşi timp de creşterea eficienţei acesteia, atât din punct de vedere energetic, cât şi economic. Lucrarea este structurată pe mai multe capitole. Primul este cel introductiv. Al doilea este legat de structura optimă a serei, aspectele termice şi electrice. Ultima parte este afectată consideraţiilor economice specifice unei astfel de exploataţii şi comparaţia cu alte soluţii.

Cuvinte cheie: gaze de seră, eficienţă, economic.

ABSTRACT. The born work as the must of cost of exploited of a greenhouses and in the same time of the growth of this efficiency, as much from power viewpoint, quotient and economic. The work is organized on the many maul chapters. The first is one introductory. The second is incident to tensional optimum the greenhouse, the thermal appearances and electric. Last part is affected the economic specific of such considerations exploitation and comparison with another solutions.

Keywords: greenhouses, efficiency, economically.

1. INTRODUCTION

Energy involved in a farm has a major economic impact on production costs. On the Romanian market but in the same situation in the international sale it is consisted a diminution of the desire of credit banking the agricultural system.

This thing is caused from objective viewpoint of the fact that the agricultural system from Romanian which is of what guy top this spade is, but and as a matter of fact that the investments in advanced systems of cultivation and process am very low.

Reduced holding costs can be both by reducing energy consumption and by automating processes performed by human operators.

Energy costs during a calendar year are the electricity that can be considered as continuous costs, while the thermal energy are variable being dependent on season.

Water supply costs are also very important in such agricultural holdings and they are continuous throughout the year.

Reducing electrical energy costs can be made in several ways:

- using a system differentiated counting day and night;
- replacing electricity consumers with single-phase or three-phase with the DC power;
- storing daytime solar electrical energy in battery system to use it in the night;

In terms of electricity has powered pump or pumps for water supply and irrigation culture have fueled the greenhouse ventilation system must be powered lighting and others less important.

The present work eliminates first point presented and it consists in a marvel of how with head can do money whence another do or do not made.

2. CONSIDERATIONS ABOUT THE BUILDING OF THE GREENHOUSE

2.1. Greenhouse structure

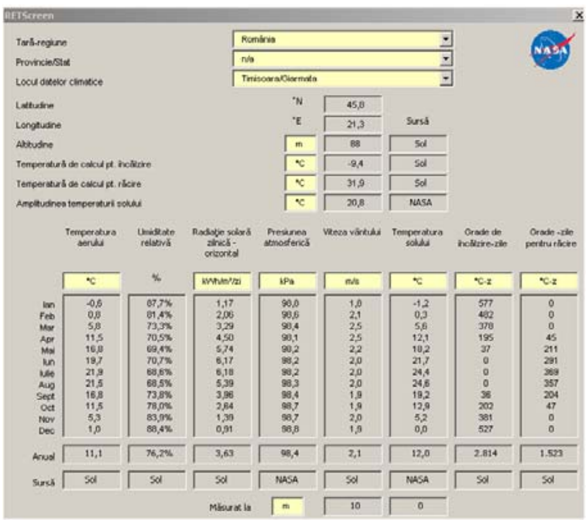
This timeliness the incorporate system is felled across as a matter of fact as the zone which in wanted this realization is a zone with periods of long-time sun, but and as a matter of fact as the investment be new in zone she can be thus organized that to permit an efficient power maxim, but and the creation of places of labor for the population from commune and respective places of practice for the students from the academic center placed the in the town Timişoara.

Must showed as the stockade of the water can to constituted incite in a must, but and in a the advantage for the equilibration of the variations of temperature among night and day, the variation of temperature among the inland air the one and from exterior, through the of a use the system regenerative heat on the system of ventilation of the greenhouse on the lateral part. Through the utilization of the funds renewable, the costs of exploitation diminish possible and produce profitable effects about possibility of support the business. In the table it is presented the variation of the temperature in Timişoara. The date is in accord with Gearmata station and West University station.

Table 1. **Minimum Timişoara temperature, West University, http://solar.physics.uvt.ro/srms/index.php?target=info&lang=ro)**

	A	B	C	D	E	F	G	H	I	J
1	Anul	2012	2011	2010	2009	2008	2007	2006	2005	Luna
2	Temperatura minima		-4	-4	-2	0	-3	-5	-3	octombrie
3			-7	-3	-4	-6	-6	-8	-5	noiembrie
4			-4	-14	-22	-10	-7	-9	-8	decembrie
5		-12	-15	-14	-15	-12	-6	-15	-16	ianuarie
6		-23	-11	-10	-13	-10	-5	-14	-22	februarie
7		-6	-7	-6	-5	-4	-1	-8	-15	martie
8	**Minimul temperaturii**	-23								
9	**Temperatura din sera**	16								
10	**Diferenta**	39								

Table 2. **Variation of Timişoara temperature, Gearmata**



RETScreen

Tară-regiune	România		
Provincie/Stat	n/a		
Locul datelor climatice	Timisoara/Gearmata		
Latitudine	°N	45,8	
Longitudine	°E	21,3	Sursă
Altitudine	m	88	Sol
Temperatură de calcul pt. încălzire	°C	-9,4	Sol
Temperatură de calcul pt. răcire	°C	31,9	Sol
Amplitudinea temperaturii solului	°C	20,8	NASA

	Temperatura aerului	Umiditate relativă	Radiaţie solară zilnică - orizontal	Presiunea atmosferică	Viteza vântului	Temperatura solului	Grade de încălzire-zile	Grade -zile pentru răcire
	°C	%	kWh/m²/zi	kPa	m/s	°C	°C-z	°C-z
Ian	-0,6	87,7%	1,17	98,0	1,8	-1,2	577	0
Feb	0,8	81,4%	2,06	98,6	2,1	0,3	482	0
Mar	5,8	73,3%	3,29	98,4	2,5	5,6	378	0
Apr	11,5	70,5%	4,50	98,1	2,5	12,1	195	45
Mai	16,8	69,4%	5,74	98,2	2,2	18,2	37	211
Iun	19,7	70,7%	6,17	98,2	2,0	21,7	0	291
Iulie	21,9	68,6%	6,18	98,2	2,0	24,4	0	369
Aug	21,5	68,5%	5,39	98,3	2,0	24,6	0	357
Sept	16,8	73,8%	3,86	98,4	1,9	19,2	36	204
Oct	11,5	78,0%	2,64	98,7	1,9	12,9	202	47
Nov	5,3	83,9%	1,39	98,7	2,0	5,2	381	0
Dec	1,0	88,4%	0,91	98,8	1,9	0,0	527	0
Anual	11,1	76,2%	3,63	98,4	2,1	12,0	2.814	1.523
Sursă	Sol	Sol	Sol	NASA	Sol	NASA	Sol	Sol

Măsurat la | m | 10 | 0

As and way of plantar can utilized the variant of equal distances between rows and respective distances alternate between rows (two approached followed of two the distant maul). The used-up maul method in the loop is it one with alternant distances between rows, for instance the distance between the rows get closer to 60 cm, and the distance between the far-off rows of 90 cm. By turns the distance between plants are due to is of 30-35 cm, thus is achieved a density of 40-45.000 of plants to hectare. For the decrease space of movement by turns these between the length are shall amalgamated with a transversal passage of 90 cm, and to brims shall be how much a passages of 60 cm. With these is can caused the optimum surface of culture and if is directed to the average shipment on the square meter is can caused the amount of which plants is cultivated and in the same time envisaging the amount of fruits produced on the unit of plant and an average price is can the minimum income which can it assure the greenhouse. If we direct to in the same time the fact that he exists a length maximum a column of irrigation through instillation of 70 to 90 meters, is can done the calculus of a length of the row. At that rate is can done a which scheme to direct to these considerations and is can caused the index of use of cultivated surface. So we have off-road bands of 70 to 90 the meters length with width of culture of 90 cm and spaces of crossing of 60 cm. The of a length corridor burn must thus to is of 72,1 to 92,1 the meters if are directed to the previous considerations and the width of 75 cm. Therefore we have an useful surface of 54,075 to 69,075 the square meters. Hereto must add the surface of movement. For the realization the easy maul of the calculi and in the same time for the of a effectuation economic correct calculi date were structured in a blackboards of guys EXCEL. For 2 corridors we have 3,3 metro, for 4 we have 6,3 metro and for 6 we have 9,3 metro.

The second problem must directed to is one incident to the sizes of the greenhouse. Due to climatic changes from zone, but and by reason of the norms of buildings, with how much the greenhouse is else high with as much I breed the costs and in the same time is reduced the economic efficiency of the investment.

Table. **3 For 2 corridors**

	A	B	C	D	E
1	Culoar		Lungime		Distanta
2	Lateral	45	minima	maxima	plante
3	Central	90	70	90	30
4	Intre randuri	60	69,1	89,1	
5	Intermediar	60	460,6667	594	Numar plante
6					
7			Suprafata		
8	Randuri	2	minima	maxima	
9	Latime totala	3,3	2,31	2,97	
10			921,33	1.188,00	Numar plante
11	Pe planta	2,5	2.303,33	2.970,00	Cantitate
12			11.516,67	14.850,00	Pret 5 lei/kg

Table 4. **For 4 corridors**

	A	B	C	D	E
1	Culoar		Lungime		Distanta
2	Lateral	45	minima	maxima	plante
3	Central	90	70	90	30
4	Intre randuri	60	69,1	89,1	
5	Intermediar	60	460,6667	594	Numar plante
6					
7			Suprafata		
8	Randuri	4	minima	maxima	
9	Latime totala	6,3	4,41	5,67	
10			1.842,67	2.376,00	Numar plante
11	Pe planta	2,5	4.606,67	5.940,00	Cantitate
12			23.033,33	29.700,00	Pret 5 lei/kg

Table 5. **For 6 corridors**

	A	B	C	D	E
1	Culoar		Lungime		Distanta
2	Lateral	45	minima	maxima	plante
3	Central	90	70	90	30
4	Intre randuri	60	69,1	89,1	
5	Intermediar	60	460,6667	594	Numar plante
6					
7			Suprafata		
8	Randuri	6	minima	maxima	
9	Latime totala	9,3	6,51	8,37	
10			2.764,00	3.564,00	Numar plante
11	Pe planta	2,5	6.910,00	8.910,00	Cantitate
12			34.550,00	44.550,00	Pret 5 lei/kg

Also with how much the greenhouse is else broad, with so also I breed the costs, because open is elder, the beams of support and the structure of support is due to is else resistant. Starting from these considerations (the report the cost economic efficiency of the investment) an optimum width falls between 3,3 meters and 9,3 meters. If we take a costs on square meter of 40 RON to the variant with 2 color and one of 110 RON to one with 6 color shall arrive at a cost of a structure of greenhouse contents between 9.240 RON for 70 the meters length and 11.880 RON for length of 90 meters, and maximum 71.610 RON for 70 the meters length and 92.070 RON for length of 90 meters. From analysis is can noticed that if to the greenhouse of little width the investment is retrieved for structure after first harvest, for one of big structure must between two and three harvests for the recovery of the investment in structure.

The height of the greenhouse is determinate by the plants that are grown in this structure. For this condition a maximum 3 meters it is good. A problem it is the situations limit of speed of the wind out is big to 100 km/h or 28 m/s have if temperature is besides –10 gr. C an adding temperature to the surface of –27 gr. C, which thing can to generate big problems.

2.2. Miss of thermal energy through the module of greenhouse

Power this logic solutions is felled across the power which loss consisted in such building and which by-paths represented the in next figure. There through solution he followed the minimum possible missed of 30 of thermo which energy consisted to the downside, but and the creation in of a greenhouse thermo ascendancy contiguous circuit of minimum 15 graduates which Celsius constituted in a elements radiant from in one absorbent. In order to supported still more many one affirmation is directed to one two variations ale the temperature of which soil on for of winter has variations between night and day of 20 to 30 degrees Celsius, in while the minimum value is in period January - February to average values of minus 10 graduate Celsius, but with minimum which limits can to arrive sometimes to –20 degrees Celsius, in while the summer deviation is maintained between night and day but maximum is moved on for day to 45 and 55 degrees Celsius.

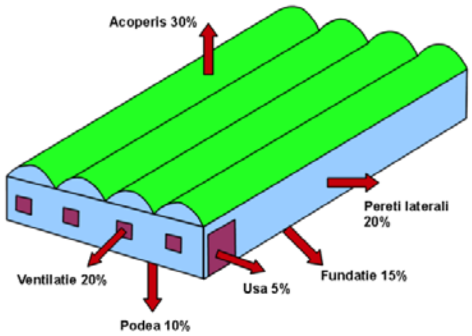


Fig. 1. Miss of thermal energy through the module of greenhouse.

If we take in consideration the variation of the temperature in Earth printed in fig.2 it is possible to see that at 1 meter deep we have 5 to 15 Celsius in all season.

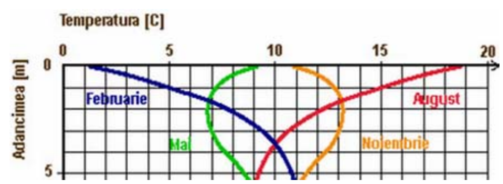


Fig. 2. Deep variation of the temperature.

For objective modular greenhouse have directed to else many sources of which heat reacts on the structure. In afterwards we presented these sources with their disposition in the drawing from section. Have next considerations take the in the calculus:

- heat is entered to the downside through floor with of a help nets of dispersion format from rectangular block of flats of the stone foresee with channel of the crossing of the water heat to 20 as far as 30 degrees Celsius;
- on the lateral part exist a system a format from a block of flats obdurate with two watery circuits wherewith pass warm water to 25 to 35 degrees Celsius to the part top and 20 to 30 degrees Celsius to the downside;
- on the wall of North exist a system of guy block of flats obdurate in which heat is stored from aback and is transmitted of a watery which reservoir assures the sustentation constantly the temperature on for vesper tine in substance speed of cooling is of maximum 1 gr./h;
- this watery reservoir the default one and among the modules of greenhouse am heated with solar panel the respective and from which interchanger assures the storage heated in afloat and her cession on for vesper tine.

From one presented is detached the conclusion as the need the spell if is can of guy which granite has a section of 0,2 * 0,4 m on a length of 70 m with a number of 76 channels on the way, therefore we have a volume of 100 m^3 the spell, dressed the in the plastic to the downside and with a length of 6.000 m of the pipe of PVC. Have thus compliant the precious calculi of 23,5 EURO to m^3 and a value of 2.350 EURO for the inferior routes.

In fig.3 it is presented the thermal transfer from the soil to inside the greenhouse.

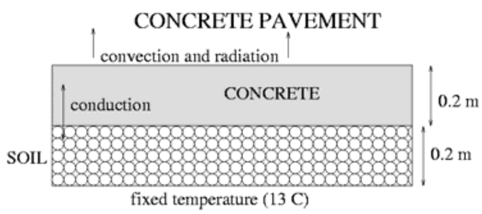


Fig. 3. Thermal transfer.

On the lateral part exterior have a belt of concrete with the depth of 0,5 m and width of 0,2 m to a compliant price of the table of 60 EURO on m^3 with role of and protection therefore have 1.300 EURO with polystyrene extruded of 20 mm which compliant thickness of the bid and a layer of the spell of 0,7 m height from which 0,5 in the earth with a thickness of 0,4 m and a length of 2 * 70 m and 2 * 38 m and have to 24 EURO a total on the way of 2.070 EURO. The maul have an wall of 0,4 m long of 38 m the high and of 0,8 m grasped with net of wire to internal the and coatings of guy insular blackboard to exterior for storage heat. The costs are of 290 EURO on the way. For polystyrene have 22 EURO on m^2 what means as have 2.370 EURO on the way.

We have thus compliant date of the amount of solar which energy can be gated in a average the calendar year she be of 1.300 kWh/m^2*year. Had obvious a maul clearly an way of casting solar energy on months and casting timetable did a study about date provide of the solar station from Weat University from Timişoara (http://solar.physics.uvt.ro/srms/index.php?target=pasor&lang=en) waves date am centralized in files of guys texts on months and on years. Envisaged yes for month one February two years most disadvantageous the si they obtained on hours and on day the amount of solar energy in Wh/m^2. If we take into consideration that 1 W is 0,85984523 kcal/h.

If we take into consideration that the part blocked is warmed and she in parallel with water from the solar panels, you results as have a totals of thermal energy compliant horary the next which table is calculating lunar depending on the emissive energy of sun. Is can noticed as in the months February, March, April, September, October, November thermal variant with water heated solar offers sufficient thermal energy, not necessary the starting of the caldron of heating. Due to this fact the costs with the matchwood this in period constitutes in a important reserve of efficiency of the costs.

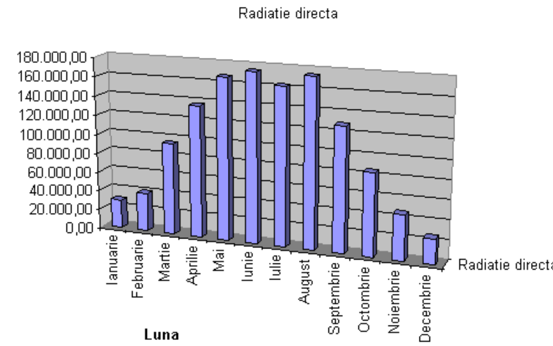


Fig. 4. Direct radiation variation in the year.

Table 6. **Temperature variation stored by month**

					piatra	panou	
Luna	Wh/mp/zi	kcal/h/mp	ore	kcal/mp	mp	mp	kcal/h
Ianuarie	966,17	830,75	7	5.815,28	109,2	1,3	92.878,38
Februarie	1.407,73	1.210,43	9	10.893,83	109,2	1,3	135.325,59
Martie	3.059,70	2.630,87	9	23.677,84	109,2	1,3	294.131,40
Aprilie	4.552,08	3.914,08	10	39.140,81	109,2	1,3	437.594,30
Mai	5.405,69	4.648,05	11	51.128,60	109,2	1,3	519.652,47
Iunie	5.815,01	5.000,01	12	60.000,10	109,2	1,3	559.000,96
Iulie	5.248,52	4.512,91	12	54.154,94	109,2	1,3	504.543,51
August	5.611,67	4.825,17	12	57.901,99	109,2	1,3	539.453,53
Septembrie	4.279,85	3.680,01	10	36.800,11	109,2	1,3	411.425,28
Octombrie	2.742,96	2.358,52	9	21.226,72	109,2	1,3	263.683,09
Noiembrie	1.567,06	1.347,43	9	12.126,89	109,2	1,3	150.642,89
Decembrie	840,39	722,61	6	4.335,65	109,2	1,3	80.787,62

If we compare the solution without heated floors heated floor and the data are obtained from the following tables shows.

Table 7. **Without heated floor**

						Temperature		
Item	Length	Height	Number	Area	Coefficient	Inside	Outside	Loss enery
Roof	70	9,686	4	2.712,08	3,9086	16	-8	254.410,46
Slide wall	70	3,5	2	490,00	3,9086	16	-8	45.965,14
Front wall	38	3,5	2	266,00	3,9086	16	-8	24.952,50
Arce	1	26,64	8	213,12	3,9086	16	-8	19.992,02
Floor	70	38	1	2.660,00	0,237	16	-8	15.130,08
								360.450,20
						Ventilation		18.022,51
								378.472,71
						Various losses		37.847,27
								416.319,98

Table 8. **With heated floor**

						Temperature		
Item	Length	Height	Number	Area	Coefficient	Inside	Outside	Loss enery
Roof	70	9,686	4	2.712,08	3,9086	16	-8	254.410,46
Slide wall	70	3,5	2	490,00	3,9086	16	-8	45.965,14
Front wall	38	3,5	2	266,00	3,9086	16	-8	24.952,50
Arce	1	26,64	8	213,12	3,9086	16	-8	19.992,02
Floor	70	38	1	2.660,00	0,237	16	20	-2.521,68
								342.798,44
						Ventilation		17.139,92
								359.938,36
						Various losses		35.993,84
								395.932,20

If you enter the cold months and inner intermediate screens get the following data in the following table.

Table 9. **With intermediate screens**

Item	Length	Height	Number	Area	Coefficient	Temperature Inside	Outside	Loss enery		Thermal screen
Roof	70	9,686	4	2.712,08	3,9086	10	-8	190.807,85		57.242,35
Slide wall lower	70	0,2	2	28,00	1,461728	10	-8	736,71		
Slide wall	70	3,3	2	462,00	3,9086	10	-8	32.503,92		9.751,18
Front wall lower	38	0,2	1	7,60	1,461728	10	-8	199,96		
Front wall	38	3,3	1	125,40	3,9086	10	-8	8.822,49		
Front wall back	38	3,5	1	133,00	0,0257952	10	-8	61,75		
Arce	1	26,64	4	106,56	3,9086	10	-8	7.497,01		
Arce lower	1	26,64	4	106,56	0,0257952	10	-8	49,48		
Intermediary screen	70	38	1	2.660,00	5,863	10	16	-93.573,48		
Floor	70	38	1	2.660,00	0,237	16	20	-2.521,68		
								144.584,01		66.993,53
						Ventilatie		7.229,20	5	
								151.813,21		
						Pierderi diverse		15.181,32	10	
								166.994,53		

In conclusion it can be seen that the heat through the solutions adopted can drop to 4 even 5 times, without affecting the functionality of the greenhouse in winter. This has positive effects in reducing emissions and in reducing operating costs in the winter.

3. CONCLUSIONS

From the analysis we can draw the following important conclusions.

First as whole the year by replacing the power supply mode of holding consumers, reduce electricity costs at least 70%.

Second by replacing the heat supply system reduces costs by 60% minimum which may result in an increase or a decrease in the profit of the sale price of the products.

The third is the use of a combined ventilation and heat using water as the heating or cooling, which will greatly reduce heat loss through the ventilation system.

REFERENCES

[1] Horticultural Journals (HortScience, Acta Horticulture etc.).

[2] Joyce G. Latimer, Extension Specialist, Greenhouse Crops; Virginia Tech: *The Basics of Fertilizer Calculations for Greenhouse Crops*, MPI Reportpublication 430-100, Produced by Communications and Marketing, College of Agriculture and Life Sciences,Virginia Polytechnic Institute and State University, 2009

[3] Alexander L Carrere: *Theory, Solar Panel Design Decision and General Information Sheet* , 1/1/2012

[4] Dr. Richard G. Snyder: *Theory, Greenhouse Tomato Handbook*, Central Mississippi Research and Extension Center, This publication is also available on the web at http://www.msucares.com/pubs/pub1828.htm