ENERGY CONSUMPTION FOR PLASTIC COVERED GREENHOUSE STRUCTURES

M. Djevic, A. Dimitrijevic

***Abstract**: In this paper different greenhouse structures were analyzed regarding energy consumption and energy productivity in winter lettuce production. Greenhouse production is still among most energy consuming branches in agriculture with very high investments and annually costs. This is the reason why plastic covering are introduced as mean of making this kind of plant production more efficient. Also, as a mean of lowering energy consumption, tunnel structures are proposed. Three different double plastic covered greenhouses were used for energy analysis. Two tunnel types, 9x 58m and 8 x 25m covered with double 180μm PE UV IR folia, and one gutter connected plastic covered greenhouse 7 x 39m. Inner folia was 50μm and outside folia was 180μm. Results show lowest energy consumption for gutter connected greenhouse. Energy out/in ration was also higher in gutter connected greenhouse. Highest energy consumptions was obtained in tunnel 8 x 25m.*
***Key words**: plastic covered greenhouse, tunnels, gutter connected structures, lettuce, energy, energy productivity*

INTRODUCTION

Greenhouse plant production is one of the most intensive parts of agricultural production. It is intensive in production per surface area and in whole year production, but also in sense of energy consumption, labor, costs and investments. This is the reason why an optimal combination of energy inputs that will make this production more energy efficient needs to be found. Producers are offered various greenhouse structures and coverings. The biggest problem is in winter production when additional heating and light are needed. In that period construction and covering characteristics shows all their qualities.

The aim of investigation was estimating lettuce winter production in three dominant greenhouse structures in Serbia and Montenegro region, regarding specific energy input, energy efficiency and energy productivity.

MATHERIAL AND METHOD

Lettuce greenhouse production was estimated regarding energy consumption and energy productivity for climatic conditions of Novi Sad region (Latitude / Longitude 44 00 N, 21 00 E) for the period autumn – winter 2003/2004. Greenhouse structures included were two tunnel types (fig. 1), 9 x 58 m and 8 x 25 m covered with double
180 μm PE UV IR folia and gutter connected plastic covered greenhouse (2) x 7 x 39 m with 50 μm inner folia and 180 μm outside folia (fig. 2).

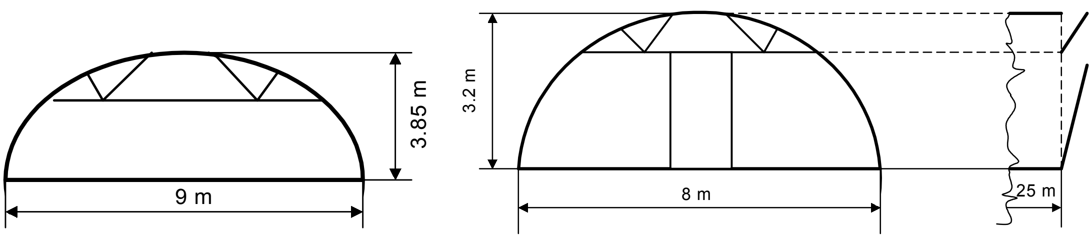


Figure. 1. Tunnels covered with double inflated folia

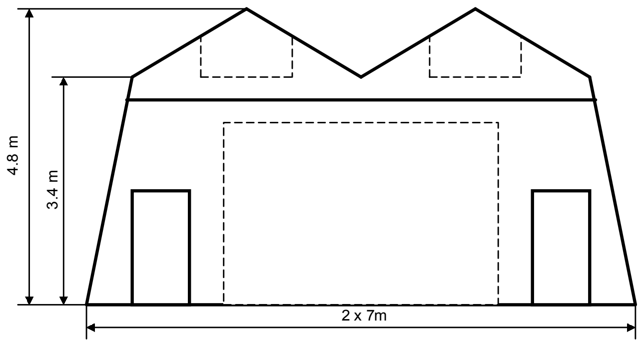


Figure 2. Multispan greenhouse covered with double folia

The method used, is based on energy input analysis (definition of direct and indirect energy inputs), energy consumption for given plant production, and energy efficiency. On the basis of lettuce production output (kg of lettuce) and energy input, energy input/kg of product, energy out/in ratio and energy productivity were estimated [2]. The parameter that describes construction was greenhouse volume per one meter of its length [m^3/m] which adequately gives the difference in single tunnels and multispan greenhouses.

RESULTS AND DISCUSION

Production technology for winter lettuce production is given in table 1. Lettuce was produced on white / black mulch folia 25 µm tickness that was 2 m wide and had alerady had openings for the lettuce planting. 20 plants were planted in 1 m^2.

Table 1. Lettuce production technology

Working operation	Material / technical system
Soil preparation	One-axle tractor Tractor 4 x 2 + rotary cultivator, 2 passages
Fertilizing	500–700 kg/ha NPK 2 x 100 kg N fertilizers
Placing mulch folia	Manually, 3 workers / day / 1000 m^2
Planting	Manually, 5 workers / day / 1000 m^2
Irrigation	Micro-sprinklers, 3.33 l/min each
Plant protection	Quadris, Sumilex
Harvesting	Manually, 6 workers / 2h / 50 boxes

Direct energy inputs

Measuring of direct energy inputs included energy embodied in heating and in fuels used by technical systems.

Table 2. Direct energy inputs for greenhouses

	Direct energy input [MJ]		
	Tunnel 9 x 58 m	Tunnel 8 x 25 m	Gutter-connected greenhouse 14 x 39 m
Greenhouse heating	3338.82	1117.32	3235.51
Fuel for technical systems	165.75	55.56	164.37

Indirect energy inputs

Measuring of indirect energy inputs included (table 3) energy embodied in fertilizers, plant protection chemicals, water for irrigation, human labor, usage of technical systems and boxes for lettuce packaging. Table 4 gives total energy consumption and specific energy consumption per m^2.

Table 3. Indirect energy input for the greenhouses

	Indirect energy input [MJ]		
	Tunnel 9 x 58 m	Tunnel 8 x 25 m	Gutter-connected greenhouse 14 x 39 m
Fertilizers	385.44	--	421.02
Fungicides, pesticides	15.12	3.36	13.44
Technical systems	4.04	4.04	4.04
Water for irrigation	268.53	115.08	16.18
Boxes	141.90	39.30	140.70
Human labor	375.00	375.00	375.00

Table 4. Total and specific energy consumption for the greenhouses

	Tunnel 9 x 58 m	Tunnel 8 x 25 m	Gutter-connected greenhouse 14 x 39 m
Direct energy input [MJ]	3504.57	1172.88	3399.88
Indirect energy input [MJ]	1190.03	536.78	970.38
Total energy input [MJ]	4694.60	1709.66	4370.26
Specific energy input [MJ/m^2]	8.99	8.55	8.00

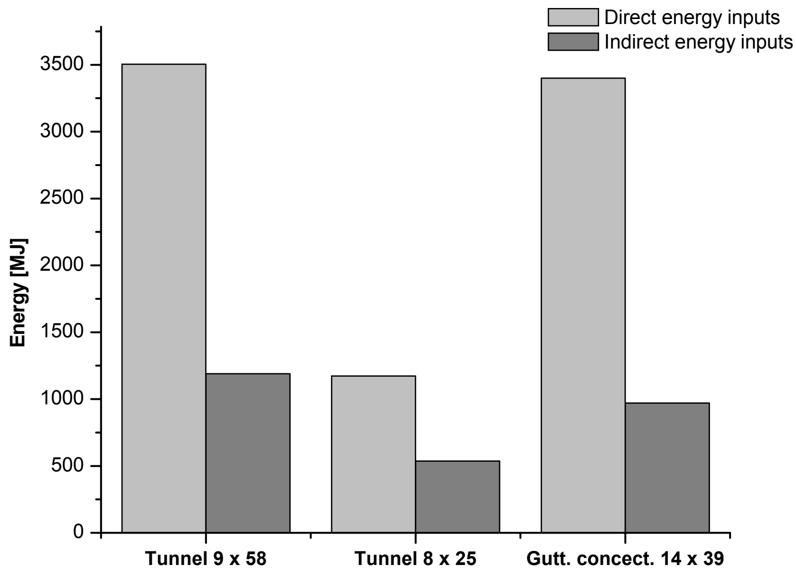


Figure 3. Direct and indirect energy inputs for the greenhouses

Results show that specific energy consumption was higher in single tunnel greenhouses that in gutter connected structures. This is in accordance with literature [1, 4] which states that the reason for this is ratio between production area and roof and wall area. In the case of gutter-connected and multi-span greenhouses this ratio is relatively big comparing to single greenhouses. Smaller greenhouse area means smaller transfer of heat through the walls which means lower energy consumption for heating.

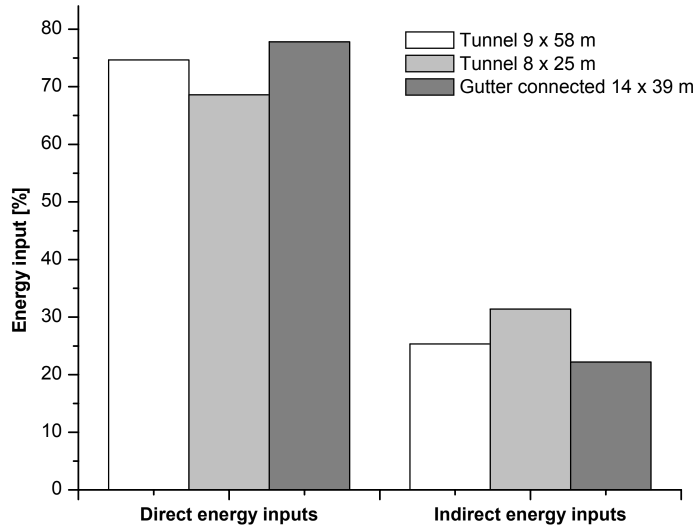


Figure 4. Direct and indirect energy participation in total energy consumption

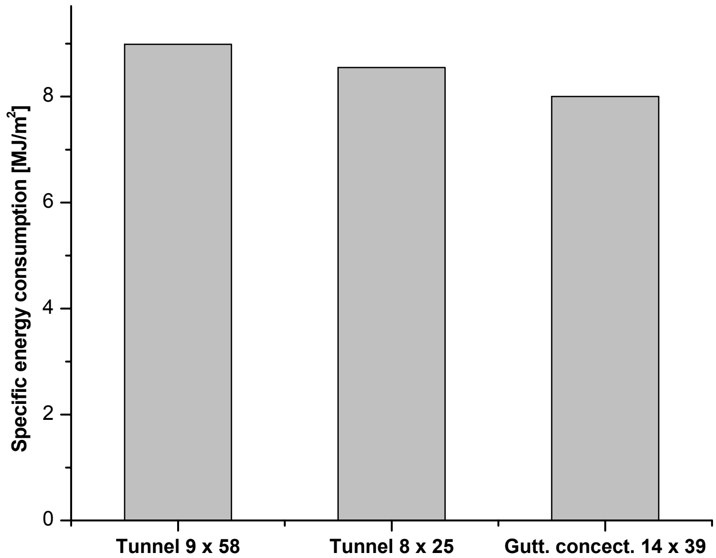


Figure 5. Specific energy consumption for the greenhouses

Energy output

Energy output is calculated based on energy value for lettuce and yield obtained.

Table 5. Yield and energy output for lettuce in greenhouses

	Yield [kg]	Energy output [MJ]	Specific energy output [MJ/m^2]
Tunnel 9 x 58 m	2753.60	1266.66	2.43
Tunnel 8 x 25 m	808.00	371.68	1.86
Gutter-connected greenhouse 14 x 39 m	2968.80	1365.65	2.50

Highest energy output was obtained in gutter-connected greenhouse and the lowest in smallest tunnel. The reason can be searched in more uniform microclimatic conditions and in lower percentage of damage caused by the nearness of the covering material. Comparing single greenhouse tunnels higher energy output was measured in larger tunnel.

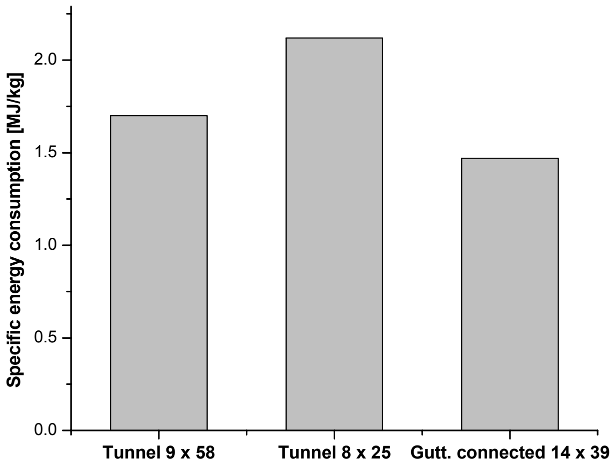
Energy analysis

Based on measured energy inputs and energy output energy analysis for lettuce energy parameters are established (table 6).

Table 6. Parameters for energy analysis

Energy parameter	Tunnel 9 x 58 m	Tunnel 8 x 25 m	Gutter-connected greenhouse 14 x 39 m
Specific energy consumption [MJ/kg]	1.70	2.12	1.47
Energy efficiency (ER)	0.27	0.22	0.31
Energy productivity (EP) [kg/MJ]	0.59	0.47	0.68

It can be seen (figure 6) that gutter connected greenhouse had lowest specific energy consumption and that highest value was calculated for tunnel 8 x 25 m. This is also in accordance with the literature [5] that says that larger greenhouses have lower specific energy consumption.



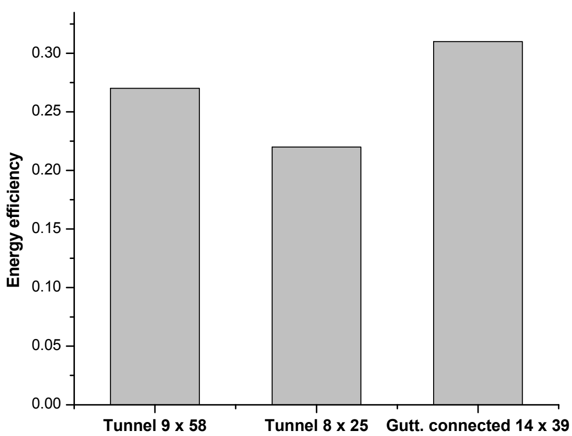


Figure 6. Specific energy concumption

Figure 7. Energy efficiency for the reenhouses

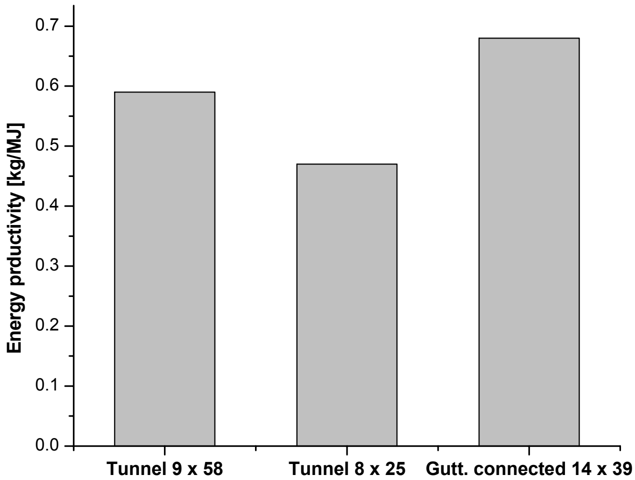


Figure 8. Energy productivity

Lower specific energy consumption and higher energy output caused the highest energy efficiency in the case of gutter connected greenhouse (figure 7) while tunnel
8 x 25 m was estimated as greenhouse with smallest energy efficiency. Obtained values show that area of Serbia and Montenegro is very suitable even for winter greenhouse production if compared with other regions [3].

Concerning energy productivity (figure 8) gutter connected greenhouse shoved highest values. This is also due to highest energy output end lowest specific energy input.

CONCLUSION

Results show that 2/3 of total energy consumption is direct energy whose greater part is energy for heating. Indirect energy inputs represent 1/3 of total energy consumption and their greatest parts are fertilizers with 30%, human labor with 30% and boxes for packaging with 15%.

Specific energy consumption shows different values for different greenhouse constructions. Lowest values were obtained for gutter-connected greenhouse (8.00 MJ/m^2) and the highest for tunnel 8 x 25 m (8.99 MJ/m^2). Gutter-connected greenhouse showed the lowest specific energy consumption (1.47 MJ/kg) compared to tunnel 8 x 25 m that had 2.12 MJ/kg.

Value for energy efficiency varies from 0.47 up to 0. 68 and shows that region of Serbia and Montenegro is very suitable for greenhouse production.

REFERENCES

[1]. Dimitrijević, M., Đević, M., Boretos, M., Miodragović, R. (1999): Design and Control Systems in Greenhouses, Technique Towards the 3rd Milenium; Haifa, Israel.

[2]. Đević, M., Dimitrijević Aleksandra (2004): Greenhouse energy consumption and energy efficiency, Energy efficiency and agricultural engineering 2005, International conference, Russe, Bulgaria (http://www.ru.acad.bg/baer/BugGHRad.pdf)

[3]. Enoch, H.Z. (1978): A theory for optimalization of primary production in protected cultivation, I Influence of aerial environment upon primary plant production, Symposium on More Profitable use of Energy in Protected Cultivation, Sweden

[4]. Hanan, J.J. (1998): Greenhouses. Advanced Technology for Protected Cultivation, CRC Press.
[5]. Nelson, P. (2003): Greehnouse Operation and Management, 6th edition

ABOUT THE AUTHORS

Prof. dr Milan Djevic associate professor, Faculty of Agriculture, Belgrade Department for Agricultural Engineering, phone: +381-11-194-606, e-mail: mdjevic@agrifaculty.bg.ac.yu
Aleksandra Dimitrijevic, B. Sc. teaching assistant, Faculty of Agriculture, Belgrade Department for Agricultural Engineering, phone: +381-11-199-621, e-mail: saskad@agrifaculty.bg.ac.yu