Potential energy cost and footprint reduction in Mediterranean greenhouses by means of renewable energy use

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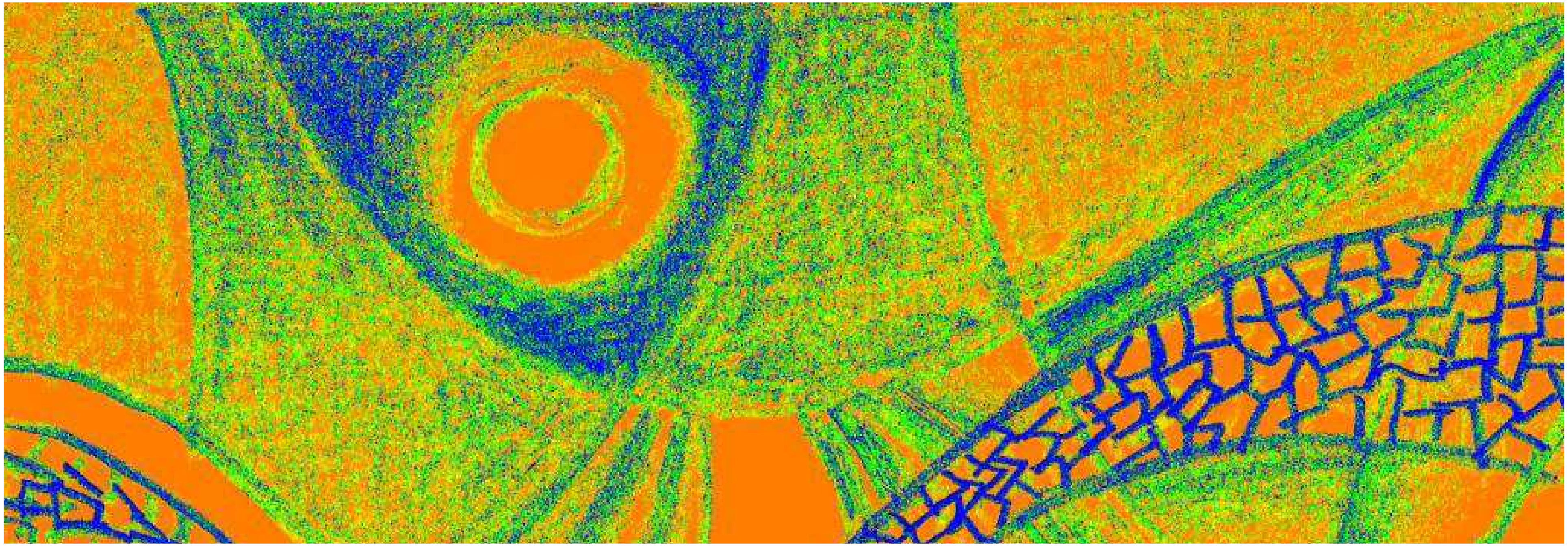

Photovoltaics can be used to supply a part of energy demand in electricity, heat and lighting of greenhouses

We studied the integration of a PV system on a greenhouse roof: (a) for electricity production, (b) to determine the effects on energy needs and (c) to calculate the greenhouse environmental impact

SEL Suggested PV and PVT Systems for Greenhouses

Solar Energy Laboratory is active for about 40 years in research regarding the design of solar thermal and photovoltaic/thermal collectors and concentrating solar energy systems for buildings, industry and agricultural sector.

SEL 1ST STUDY FOR GREENHOUSES (2005)

Fresnel lenses for solar control and energy demand of greenhouses

(Presented at Leuven, Belgium)

25% of heating load
50% of ventilation and cooling load
75% of electricity for electrical devices and night lighting

Total amount 50% of energy demand

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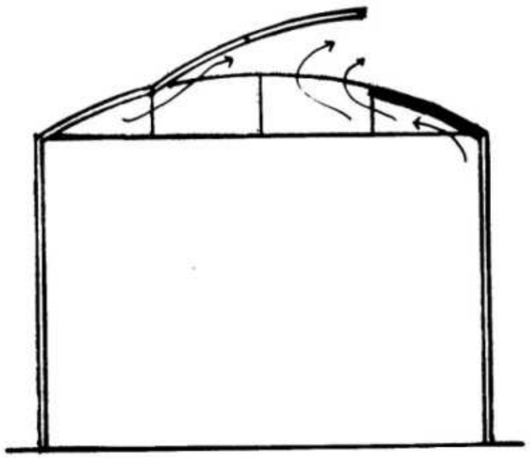
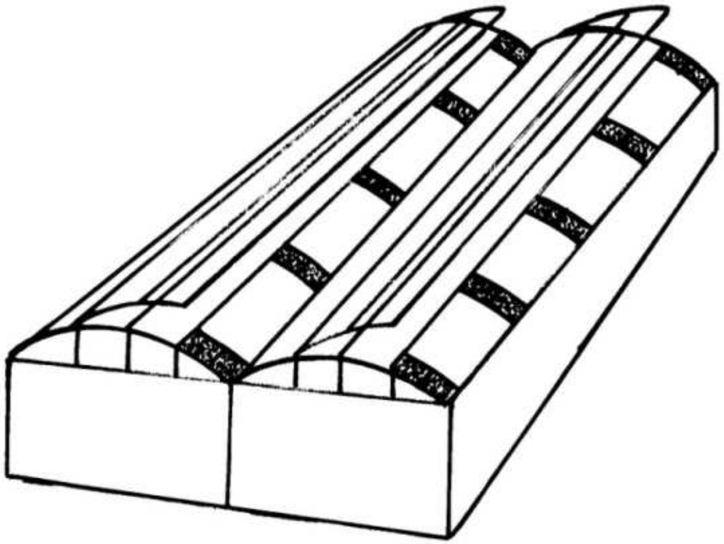




SEL 2ND STUDY FOR GREENHOUSES (2006)

(Presented at Almeria, Spain)

PV/T panels on greenhouse roof

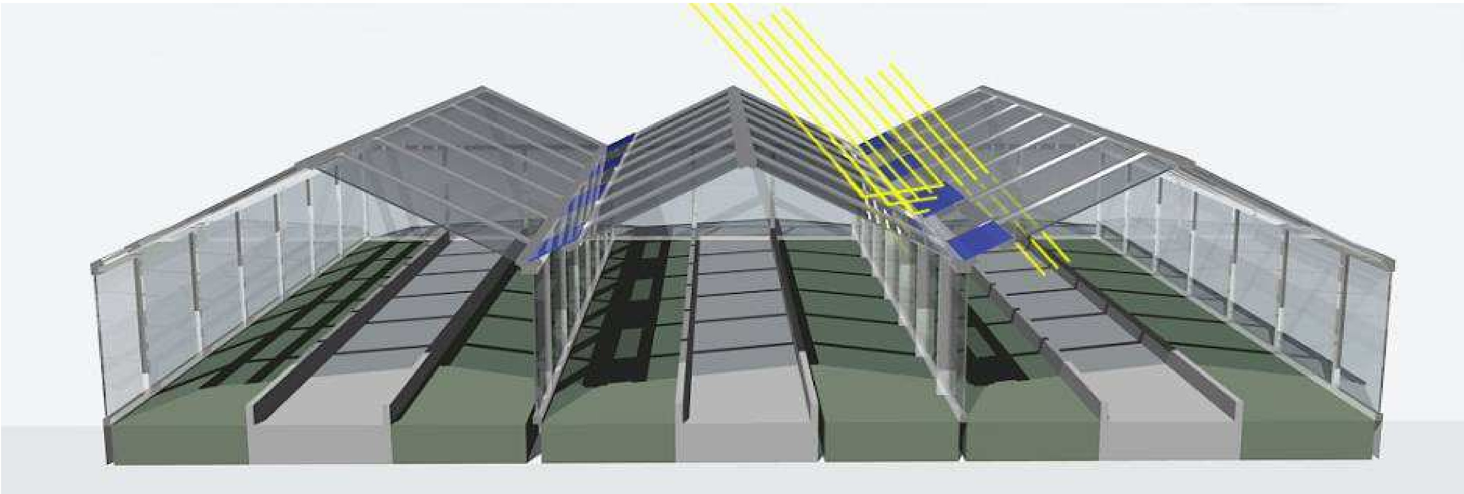
Covering 20% of greenhouse roof surface and achieving 50% of the total load

Effective installation of PV panels on greenhouse roofs

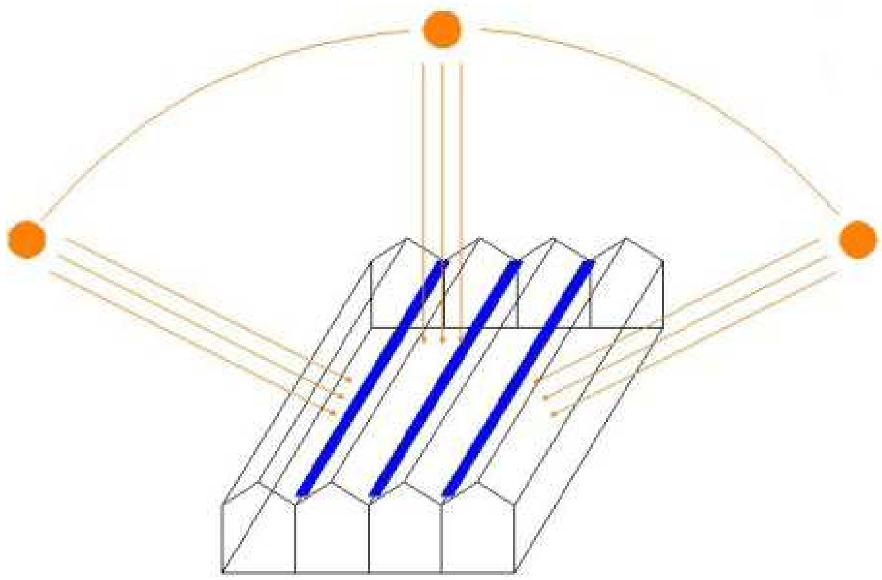
At greenhouses with sequence pitched transparent roof and PV panels south facing roofs, the opposite roof - facing north – can contribute to electricity output increase by the additional input from the reflected rays towards PV panels.

PVs can contribute to night lighting of plants inside greenhouses, extending their photosynthetic operation time.

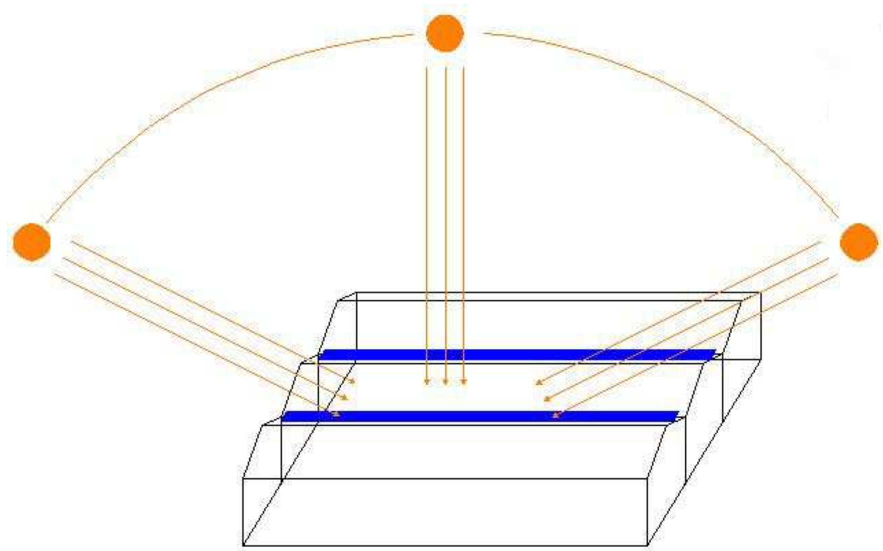
LED type lamps could be mounted suitably under the greenhouse roof mounted PV panels, to be used for the night lighting.



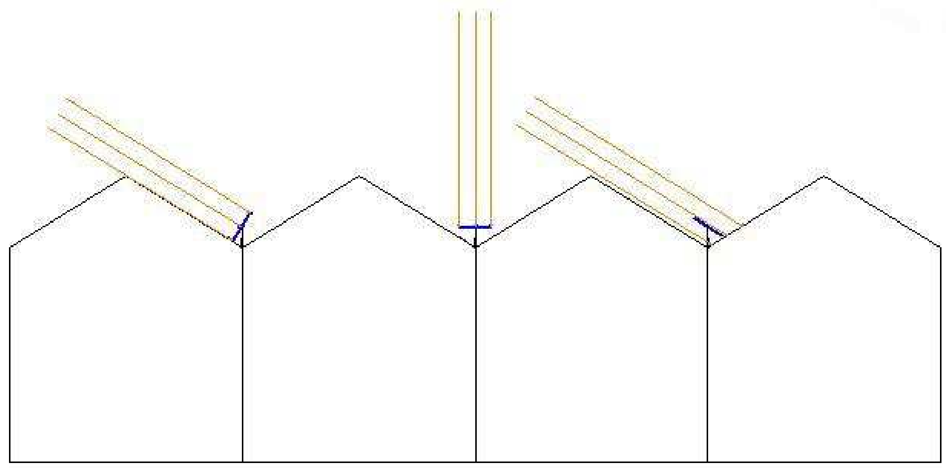
Installation modes of PV panels



A. North-South sun tracking mode



B. East-West sun tracking mode



C. PV panel rows between greenhouse spans and tracking mechanisms, to increase electricity output

METHODOLOGY

In our study, the simulations are performed for an East-West greenhouse **of 1 ha** at Central Greece and total **roof area about 10.500 m^2.**

PV panels of **250 W** and of about **1.7 m^2** aperture area each, are mounted to the south side of greenhouse roof.

(a) installation of **40 panels** with a total area of about **70 m^2** and **0.65%** of the total roof area (**10 kWp**)

(b) installation of **400 panels** with a total area of **700 m^2,** that is about **6.5%** of the total roof area (**100 kWp**).

It is assumed that case (a) will have no effect on crop production and case (b) may result to 5% yield reduction.

Location of the application is Larissa, Central Greece and the results were obtained using RETScreen4 tool. Economic results for the PV system are not considered in this work.

RESULTS AND DISCUSSION

The intallation of PV panels to greenhouse (GIPV) would provide
(a) 13.5 MWh per year and (b) 135 MWh per year

1 ha tomato greenhouse located in Central Greece would needs about <u>2.400 MWh</u> per year to cover heating and electricity needs.

Operating system	Energy (MWh)
Heating	2260.5
Pad and fan cooling system	91.2
Air mixing fans	20.5
Fertigation	5.0
Sorting and packaging	0.8
Cold storage	5.0
Other	3.4
Total	2396.4

HEATING: 2.260 MWh - ELECTRICITY: 136 MWh.

case (a) can cover about 10% of the total electricity energy needs
case (b) can completely cover the electricity energy needs.

Life cycle impact of a 1 ha conventional greenhouse and a 100 kWp greenhouse

The results are expressed by functional unit (1 tonne of tomatoes)

Conventional greenhouse

		Functional unit		TOTAL	Structure	Auxiliary equipment	Climate control system	Fertiliser	Pesticides	Waste
				Conventional greenhouse						
ADP	Abiotic depletion, kg Sb eq	1 ton	Tomato	**11.065**	0.164	1.306	9.206	0.378	0.007	0.004
AAP	Air acidification, kg SO_2 eq	1 ton	Tomato	**5.666**	0.084	0.827	3.720	1.029	0.005	0.002
EUP	Eutrophication, kg PO_4^{---} eq	1 ton	Tomato	**2.170**	0.035	0.447	0.477	1.207	0.003	0.001
GWP	Global warming, kg CO_2 eq	1 ton	Tomato	**1773.830**	18.717	168.281	1419.637	165.797	0.874	0.524
POP	Photochemical oxidation, kg C_2H_4	1 ton	Tomato	**0.235**	0.004	0.035	0.184	0.012	0.000	0.000
CED	Cummulative energy demand, MJ	1 ton	Tomato	**25945.085**	400.003	3699.241	21065.503	753.013	16.932	10.393

Greenhouse with Photovoltaics (life cycle analysis is not considered for PVs)

		Functional unit		TOTAL	Structure	Auxiliary equipment	Climate control system	Fertiliser	Pesticides	Waste
				Photovoltaic greenhouse						
ADP	Abiotic depletion, kg Sb eq	1 ton	Tomato	**10.540**	0.172	0.267	9.691	0.398	0.007	0.004
AAP	Air acidification, kg SO_2 eq	1 ton	Tomato	**5.286**	0.088	0.192	3.915	1.083	0.005	0.002
EUP	Eutrophication, kg PO_4^{---} eq	1 ton	Tomato	**1.869**	0.036	0.042	0.502	1.284	0.003	0.001
GWP	Global warming, kg CO_2 eq	1 ton	Tomato	**1718.482**	19.702	28.446	1494.355	174.524	0.920	0.536
POP	Photochemical oxidation, kg C_2H_4	1 ton	Tomato	**0.221**	0.005	0.010	0.194	0.012	0.000	0.000
CED	Cummulative energy demand, MJ	1 ton	Tomato	**24020.807**	421.056	604.427	22174.214	792.645	17.823	10.642

The use of PVs in the greenhouse results in:

5% decrease of abiotic depletion impact and global warming

7% reduction in acidification

14% reduction in eutrophication.

Reduction of auxiliary equipment in all impact categories.

The rest of greenhouse production processes (fertilisation, pests control and waste) **were not significantly affected**, since they are only indirectly affected by PV system, due to the assumed 5% reduction of crop yield.

1 ha conventional greenhouse could produce **450.000 kg of tomato/year** Assuming **a 5% reduction** of crop due to shading from the PV panels, the PV greenhouse will produce about **22.500 kg less tomato**.

For a mean selling price for tomato about **0.85 euro per kg**, then the total **economic loss** from the production will be about **20.000 euros**.

The produced electricity of **135 MWh corresponds to 13.500 euros** and if we add PVs contribution to energy saving in winter and reduction of cooling load in summer, then PVs **can balance the total electrical load**.

CONCLUSIONS

A greenhouse roof covered by 6.5% with PV panels (GIPV) can **cover completely the electricity needs** of the GH auxiliary processes, with about a corresponding reduction of the entering solar radiation to greenhouse.

The electricity produced from PV panels affects positively the environmental indicators, **reducing** therefore the Life Cycle **impact** of the greenhouse.

The application of hybrid PV/T, or other solar energy and renewable energy systems, could contribute to cover thermal needs, reducing therefore the energy demand and environmental indicators of these agro-constructions.

In case of a higher roof covering percentage (e.g. 20%) and mainly by PV/T collectors, the produced electricity can cover GH all electricity needs and the rest to drive Heat Pumps covering about 50% of GH thermal needs.

Thus, the application of PVs or hybrid PV/Ts to organic greenhouses can reduce the consumption of the conventional energy sources (oil, gas, coal) and contribute to the achievement of sustainable agro-units.

Thank you for your attention

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