SUSTAINABLE GREENHOUSE HORTICULTURE IN EUROPE

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ABSTRACT - The European greenhouse horticulture represents one of the most intensive energy sector in agriculture and strongly contributes to increase the energy and environmental vulnerability within regions having a large greenhouse farming systems. Specifically, the European greenhouse farming sector is facing a trend that responds to the changing consumer's demands in a society that, globally, is increasingly affluent but more aware about some negative consequences, such as high energy-demand processes, and CO_2 emissions. About 200,000 hectares of greenhouses in Spain, Italy, The Netherlands and Greece is the estimated covered surface, with not less than 3.4 MTOE of energy consumption and 9.2 MtCO2eq, and an yearly economy value of 7 billions of Euros. The installed energy power load of greenhouses in Europe depends on local climate conditions, and varies from 50-150 W/m^2 (Southern regions of Europe) to 200-280 W/m^2 (Northern and Central regions), while complete conditioning could even reach an energy load of 400 W/m^2 (heating, lighting, cooling). Nowadays, the proportion of renewable use in the total energy consumption of greenhouse farming in Europe is very low, and there are no clear priorities set in this area, yet. Comprehensive and complete studies that evaluate the opportunities of renewable options in greenhouse sector are still not completeted. This, strongly hinders the process of setting concrete goals and legislative targets to support a wider introduction of sustainable energy technology, and appropriate legislation in greenhouse regions of Europe. This paper deals with the proposal of supporting the organization of a sustainable greenhouse agriculture, based on renewable energy sources, i.e. geothermal energy at low temperature, photovoltaic solar energy and solid biomass, in tune with the specific local assets, the local geo-climatic conditions and the protection of landscapes rather than with a careless perspective for local environment and potential societal costs.

Keywords: energy efficiency, greenhouses, solid biomass, photovoltaic technology, geothermal energy

1. INTRODUCTION

The greenhouse horticulture sector in Europe represents an important economic reality in countries such as Italy, The Netherlands, Spain, Greece, and one of the most intensive energy sector in agriculture (Tab. 1). As general figure, in Europe are operating about 200,000 hectares of greenhouses, of which about 30% with permanent structures, and provided with acclimatization systems using fossil fuels. Between the most important European countries regarding to the surface covered with greenhouses (i.e.: Spain, Italy, The Netherland and Greece), it has been estimated not less than 3.4 MTOE of primary energy consumption with 9.2 $MtCO_{2eq}$ and a total economy of 7 billions of Euros. The installed energy power load of greenhouses depends on local climate conditions and varies from 50-150 W/m^2 (Southern regions of Europe) to 200-280 W/m^2 (Northern and Central regions) while complete microclimate conditioning could even reach energy load of 400 W/m^2 (heating, lighting, cooling) [5]. The greenhouse sector in Europe should limit its use of fossil fuels, therefore reducing its CO_2 emission to positively respond to the European Directives on energy, renewable energy, energy efficiency and environment [7, 9]. Since it is general conviction that the oil price will continue to increase for the coming years in Europe, great efforts must be made to develop actions for supporting the use of the large availability of solar energy irradiation, the abundant resources of both geothermal energy and solid biomass. Amongst the actions to step up the development of a sustainable dimension of the greenhouse sector, high significance gains the enactment of laws and regulations to re-orient the greenhouse agriculture in line with both the Kyoto Protocols.

Tab. 1. Energy and economy in some of the most important countries for greenhouse agriculture

Country	Greenhouse[a] surface (ha)	Economics[b] (€)	Heating[c] (MWh_t)	Electricity[d] (MWh_{el})
Italy	30,000	3 billion	706,786	24,830
The Netherlands	10,311	6,8-7,7	29,510,800	3,723,000
Spain	43,964	1.5*	989,627	33,623
Greece	5,646	0.5	87,644	1,700
Total	**89,921**	**About 12.0**	**31,294,857**	**3,783,153**
TOE			2,691,358	760,414
MTOE			2.7	0.77
$MTCO_2$			7.5	2.1
TCO2eq			7.2	2.04

a. referred to both plastic-houses and glass-houses;
b. referred to yearly value, including plant products and construction materials of greenhouse;
c. referred to yearly energy consumption;
d. referred to yearly electricity demand of greenhouse users (ventilation, opening, pumping);
* greenhouse construction materials are not included.
Conversion factors:
- 0.0860 TOE/MWht.
- 0.201 TOE/MWhe.
- 1 TOE equal to 2.81 tons of CO_2 emissions.
- 2.683 TCO_{2eq}/TOE (IPPC, revised in 1996).

Source: The Regulatory Authority for Electricity and Gas of Italy, 2009.

Elaboration of authors from data EUROSTAT 2008 and 2009, national statistics and bibliography.

In addition to strictly occupational effects, the development of sustainable greenhouse system surely can increase on-site income and puts into motion a virtuous cycle which local communities can only benefit from, i.e. more circulation of money due to investment in technologies and infrastructures, and increase in collection of local taxes for authorities.

2. METHODS

Geothermal resource at low temperature. The use of hot warm water from geothermal or industrial thermal effluents at low temperature as energy for greenhouse heating has much potential of supplying a great part of the energy needs in greenhouse agriculture. Geothermal water at low-temperature is compatible with a wide range of heating system designs including forced-air distribution systems, water-to-air heat exchangers, plastic pipes and finned tubes, liquid-based radiant heat in the floor, bench-mounted-liquid based radiant heat, and direct soil heating.

The advantages and disadvantages of these heating systems have been investigated by several experimentations, with a wide collection of data and results which showed that all these systems are able to produce heat energy ranging from 30 to 70 W/m^2 as referred to the horizontal projection of ground occupied by the system [1, 10]. The feasibility of this resource of thermal energy for greenhouse heating is mainly for providing base-thermal load with peak thermal load covered by traditional installations. There are two main approaches under which greenhouse owners can operate: retrofitting an already-in-use system or building new greenhouse plants and introducing new energy technologies to make cost-effective use of geothermal energy. In the first approach, the agriculture company can use an existing geothermal well and operate the entire geothermal energy system from the well to the heat delivery equipment in the greenhouse structure. This option includes that the cost of energy delivered to the greenhouses is not affected by actions of others but must provide by himself all actions requested for maintenance of geothermal installations. In the second approach, the agriculture company could purchase geothermal heat from the owner of the low-temperature effluent resource. Both approaches require tax considerations, permits, national, regional and municipality laws and regulations. A recent type of geothermal space heating is the application of ground source heat pump, which is mainly adapted in systems providing only space heating for greenhouses [15].

A ground source heat pump uses underground heat exchangers of different types to extract heat from usually shallow depths (a few meters to a few hundred meters) and use it for space heating during the cold season. Several data report that simple horizontal ground-source heat pump configurations can supply 20-35 W per m^2 of ground surface occupied by the loop. It is possible with some research and more optimization to have 40-45 W per m^2 from a simple low cost ground loop. So, applied to 1000 m^2 greenhouse, a power of 45 kW can be extract from the earth.

Surely, some electricity from compressor (if COP = 5 part of energy from electricity and 4 parts from ground) so if COP = 5 then total energy delivered will be 60 to 66 W per m^2. Other configurations (more dense but 30-50% more expensive) already give around 75 W per square meter plus the electric power load(i.e. total energy up to 100 W_{th}/m^2. The availability of these systems can be 100% of the period of heating (and cooling). In order to calculate the whole energy deliverd during one year, if the system operates as much as 25% of time a 100 W_{th}/m^2 geothermal heat pump can give as much as 100 W_{th}/m^2 x 0,25 x 8760h = 219 kW_{th}/m^2/year, at very low operating cost lower than 50% of conventional energy.

2.1. PV solar

During the last decade, photovoltaic solar energy as sustainable option for greenhouse acclimatization in regions characterized by high irradiation has been raising importance, in accordance with both the growing market of renewable energy and the demand coming from society for reducing energy fossil fuel consumption and emissions of CO_2 [11].

In most Mediterranean areas, annual solar radiation can reach an average of 1500 kWh/m^2/year, but some areas of Spain, Italy and Greece present more than 1800 kWh/m^2/year. Among the immediate applications for PV systems in greenhouse, are the following ones:

- irrigation control (pumping, automation, electro valves, computers)
- fertilization control (automation, recycling of the nutrient solution, fertilizers mixing) climate control:
- ventilation (vents motorization and automation, electrical fans);
- cooling (cooling pads, fog-systems);
- shade screen (motorization, automation);
- heating (when heating requirements are low);
- photoperiodic lighting (5 to 10 W m^{-2}).

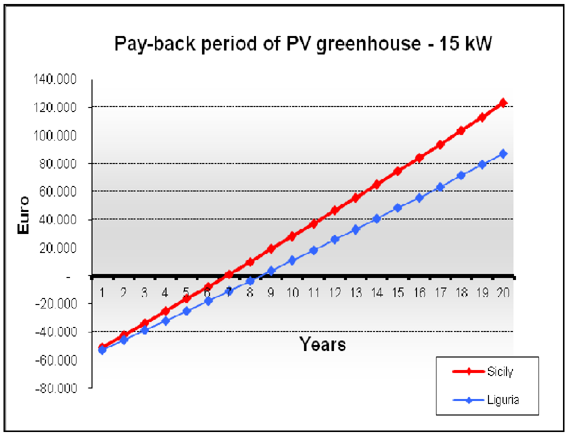

Fig.1. Comparison of pay-back period for PV greenhouses located in different climatic areas of Italy areas in Italy (Source: Report "Stato dell'arte e prospettive di sviluppo delle tecnologie per la produzione di Energia Elettrica, di Calore e di Biocarburanti e delle tecnologie per l'Efficienza Energetica". ENEA, January 2012 (in Italian).

A greenhouse requires a yearly average power electrical requirement ranging from a maximum of 90,000 $kWh_{el}.ha^{-1}$ for greenhouse with a good climate control (heating, cooling or ventilation) to 20,000 $kWh_{e}l.ha^{-1}$ for very low technological greenhouse structure. ENEA data on the PV technology as electricity demand for 1 ha of greenhouses estimates not less than 32,000 kWh in the southern Italy area.

Assuming PV module efficiency (ηPV) equal to 0.13, a 7.5 m^2 panel area is needed to generate 1 kWp DC peak power and an annual yield of 1500 kWh_{el}. This leads, on yearly basis, to a value of DC peak power installed to generate 1000 kWh_{el} equal to 1000/1500 = 0.66 $kWp.(1MWh_{el})^{-1}$ to contribute the greenhouse energy demand [2, 3, 6]. Assessment European average cost for PV power generation turns out to be around 2-3 $€.Wp^{-1}$ (VAT and installation not included), especially when poly-crystalline solar cells are used. Figure 1 shows the time to re-pay the investment (pay-back period) of 15 kWp PV installations, based on multicrystalline silicon plants, installed in Italy at different latitudes (the region Sicily at latitude 37° has the highest insolation in Italy, and the region Liguria at latitude 44°).

Apart from the estimated emissions associated with the manufacturing, transport and future decommissioning of PV plants, of importance are also the negative impacts in terms of vision and land use (between 2.5-3.0 hectares per 1 MWp) on the agro-ecosystem, which today are not properly accounted neither by the governments and the producers, nor by the consumers of energy. Such costs should be seen in comparison with the benefits for better quality environments due to the avoided CO2 emissions, and for the advantages in terms of new income-productive activities associated to the greenhouse industry. The external costs (socio-environmental and health costs) for Southern Europe would be 0.15 $c€.kWh^{-1}$, with a corresponding GHG emissions between 21-45 g CO_2-$eq.kWh^{-1}$ [8].

2.2. Solid biomass as energy source

It was estimated that not less than 300 million tons crop residues and over 230 million tons green residues and animal wastes are produced in Europe as unutilized by-products, which can be made available for partial substitution of commercial energy sources in the future (data from FAO). According to EU's energy projections, the use of biomass for energy generation in Europe, today estimated around to 180 Mtoe, would reach 210-250 Mtoe by 2030 to meet the European renewable energy targets. Among the different wood energy opportunities which are taken into consideration hereafter are those relating to heating market of chip, pellet and briquette.

According to ENEA data, 150 tons per year of biomass are requested for greenhouses of 1000 m^2 with at least 2,000 hours of heating. Averagely, the cost of a modern biomass boiler is about 325 €/kW till 100 kW, 156 €/kW for size of more than 100 kW and till 500 kW, and 136 €/kW for biomass boiler with energy load of more than 500 kW and till 1,000 kW. As fas as the price of fossil fuels together with the environmental and energy security concern continue to increase in Europe as in the rest of the world, bioenergy raises higher interest as sustainable fuel for greenhouse agriculture and small scale district heating plants applications. As reported from a number of investigations, biomass energy is capital intensive as initial investment and remain low as running costs in respects of the traditional fossil energy technologies. Evaluations made for the greenhouse horticulture in Italy with solid biomass show that the years necessary for re-pay the investment (pay-back period) decrease in relation to the increase of the installed power biomass boiler (Fig. 2). The economy of biomass heating strictly depends both on actual fossil fuel prices and on availability of government incentives, and this makes that most often the energy market demands/loads and the tax facilities (incentives or income tax exemptions) are the final rule for defining the real biofuels price.

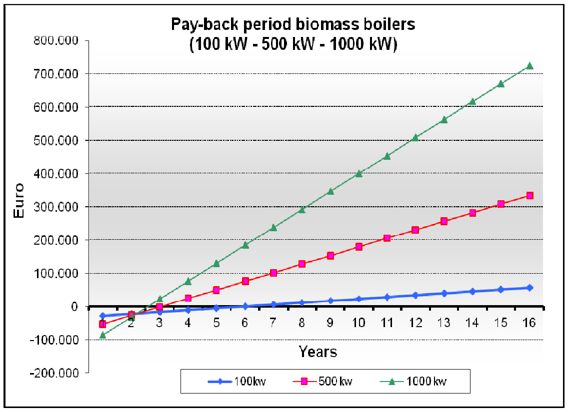

Fig. 2. Comparison of pay-back period for different energy load of biomass boilers (Source: Report "Stato dell'arte e prospettive di sviluppo delle tecnologie per la produzione di Energia Elettrica, di Calore e di Biocarburanti e delle tecnologie per l'Efficienza Energetica". ENEA, January 2012 (in Italian).

2.3. Energy Performance Certificates (White Certificates)

Europe-27 has placed the promotion of energy efficiency among the priorities of its energy policy. The Directive 2006/32/EC provides further pointers for encouraging energy efficiency, as an essential prerequisite for achieving the renewable energy and CO_2 reduction targets. The European Energy Efficiency Action Plan 2011 points to the role of energy efficiency as an essential tool for reducing consumption among Member Nations, in order to achieve the more ambitious goal of a reduction of 20% by 2020 and to stimulate the efficient use of resources.

Directive 2006/32/EC establishes that Member States must draw up an Energy Efficiency Action Plan aimed at achieving an overall national indicative energy savings target by 2016, equivalent to 9% for the ninth year of application. The target is to be reached by way of energy services and other energy efficiency improvement measures, such is the incentive mechanism consisting of the creation of a market in Energy Performance Certificates or White Certificates, which attest the reduction in consumption of primary energy resulting from energy efficiency measures and actions.

The White Certificate mechanisms aimed at projects that adopt efficient energy-saving technologies, enable the adoption of renewable technologies for heating, including: solar panels for the production of hot water, high-efficiency heat pumps, low temperature geothermal systems, or systems that use vegetable products and organic or inorganic refuse, etc. [13]. To counter energy costs on the one hand and the need to reduce CO_2 emissions on the other, greenhouse agricultural businesses can now no longer delay either the introduction of environmentally friendly energy technology or the adoption of innovative agricultural practices, systems, production processes capable of maximising the energy efficiency of the agricultural cycle and the use of locally available renewable energy.

Table 2 reports the schedule of energy-efficient measures proposed in Italy.

Tab. 2. Energy efficiency for greenhouse agriculture

Systems and devices to increase energy efficiency	**Benefits to the company, agriculture and the micro-climate**
Greater insulation of the greenhouse	Reduction of surface area losing heat
Use of "thermal blanket" systems	Reduction in the volume of greenhouse to heat
Strategies of controlling and planning temperatures and relative humidity	Heating of the air correlated to the intensity of external light
Systems and techniques for passive accumulation for solar heat	Maximisation of solar heating
Transparent/filtering covers for regulating the transparency of Covers that increase the diffusion of direct sunlight	Increase in visible radiation (PAR) and reduction in infrared radiation (NIR)
	Increase in visible ventilation for cooling
Increasing the heat dispersing area of windows	Greater natural ventilation for cooling
Cogeneration systems	Use of local energy resources (biomass)
Low-energy bulbs or Light Emitting Diode (LED) lighting	Improvement of vegetable productivity and increase in the life cycle of light bulbs
Biomass boilers, geothermal heat pumps, photovoltaic systems	Energy innovation, reduction in emission of CO_2

3. RESULTS AND DISCUSSION

The greenhouse horticulture sector has an important role to play in the future European agriculture economic and this asks both the growers and the farmers to adapt the energy technology to changing circumstances and market pressure as well, and to incorporate the energy efficiency policy, the technology innovation and the renewable energy sources. Renewable energy resources (geothermal energy, PV technology and solid biomass) together with the use of sustainable plant process for greenhouses are recommended as one of the cornerstones in order to innovate the greenhouse agriculture in Europe.

The governments and stakeholders should contribute by providing special financing to encourage both the private enterprises and the growers to invest in renewable energy and innovative technologies. Furthermore, the research and the technicians should assist growers by assessing the potential of each local energy source available on the specific site, and by estimating the energy investment cost required to use it. Based on these data, the task of elaborating a conceptual design of sustainable greenhouse districts and its implementation must be carried out with care.

Much attention should be provided by researchers, authorities and stakeholders to inform growers on the potential impacts on the agriculture traditions and the environment in order to increase acceptance and penetration of innovation and renewable technologies.

4. CONCLUSIONS

The prospects for growth of a sustainable greenhouse industry based on geothermal, biomass and photovoltaic solar technologies should be excellent. The integration of renewable energy resources and technologies into existing greenhouse agriculture represents a great opportunity of supplying most of the yearly energy demand in European horticulture. However, one of the most important aspects for greenhouses farms is to document the technical and economic performance and reliability of local available renewable resources as well as the impact of renewable energy installations on greenhouse horticulture productivity and agriculture territory.

Renewable technology offers an opportunity to strongly reduce both the fossil energy for greenhouse acclimatization and the CO2 emissions of agriculture in Spain, Italy, The Netherland and Greece. Europe is currently supporting either the policy of developing of renewable energy or the decreasing of CO2 emissions. The governments and the authorities should encourage growers and companies by providing incentives to improve the Energy Efficiency and to foster the application of renewable resources. Of particular interest for supporting the introduction of renewable technology in greenhouse horticulture is the mechanism of White Certificates (WC) or Energy Performance Certificate (EPC). The mechanism lays down that White Certificates will be issued in response to energy savings verified and certified by authorized authorities. The Italian White Certificates as mechanism to improve Energy Efficiency is internationally recognized as a benchmark, since no other country has implemented such a well-defined system in agriculture. These kinds of encouragements and economic incentives, however, should be supported with adapted regulatory measures, programs of research, and demonstration activities to allow renewable greenhouse horticulture to substitute in the short term traditional greenhouse horticulture activity.

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