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Energy Consumption of Nurseries in Ancona District and Investigation on Production Systems

Alessio Ilari*, Daniele Duca[a], Giuseppe Toscano, Giacomo Ventura, Ester Foppa Pedretti, Roberto Luciani

Department of Agricultural, Food and Environmental Sciences, Marche Polytechnic University, Via Brecce Bianche, 60131 Ancona, Italy
a.ilari@pm.univpm.it

The primary aim of this study is to analyse the efficiency of heating systems focusing attention on the consistency between the estimated consumption based on the declarations made by greenhouse operators and the selected estimation model, and the amounts of fuel officially assigned by the public body. The Italian greenhouse cultivation systems are characterized by a relevant use of economic and material resources. Based on the periodical survey on agriculture carried out by the Italian government, the total national surface devoted to production under greenhouse was about 42,500 ha (ISTAT, 2016) according to ISTAT in 2011. Although many are the contributors to the equivalent energy consumption (about 16 Mtoe for the entire agriculture sector) (Campiotti, 2016), the protected cropping systems account for a consistent part of the total load (considering the limited cultivation area). The average consumption of fossil resources (for heating) and electricity was 23 MWh/ha and 0.8 MWh/ha respectively. In Marche region, the surface covered by greenhouses was about 203 ha (0.7 % of the total in Italy in 2011) (ISTAT, 2011). Focusing on consumption and related emission of fuels used for direct heating, the diesel (the most used fuel in Marche region) (Campiotti, 2013) is responsible of a medium emission level (266 g CO_2 eq/kWh). In this study, the authors investigated the use of energy as fuel for heating in nursery systems, considering different production systems. Greenhouse types were grouped considering the characteristics of building structure, crops and type of heating system. Collected information regards: type of greenhouse and cover; heated surface; plants produced; installed power of heating system; operational period; fuel type; average fuel consumption; efficiency and greenhouse requirements. More in detail, based on bearing structure, the typologies of greenhouse individuated are three, eighteen types of cover considering the material used and five typologies of fuels/biofuels or a mix of them. The original sample consists of 62 Small and Medium Enterprises (SME) involved in nursery productions. Regarding the type of structure, the most represented types are tunnels with or without vertical walls or mixed systems. Plastic materials are the most used for cover representing the 76 % of all the materials employed. The most used fuel for heating is diesel (in 84% of enterprises). The covered surface varies between 0.004 ha and 4 ha and 89 % of nurseries have a covered area smaller than 1ha (mean 0.2 ha). The average heating power installed for diesel systems is about 250 kW, with about 59 l/day of fuel combusted. The research highlights the relation between the different aspects characterizing each greenhouse type. The goal of the study is to give useful information to the policy maker for a correct incentivization of greenhouse production by providing data of energy consumption more linked to the real greenhouse system employed in the region. The results of this study could support the creation of a more virtuous production chain and could support regional policies also on energy use efficiency and GHG emissions reduction.

1. Introduction

The efficient energy use is the first issue pointed out in the European development strategy. In order to allow a smart, sustainable and inclusive growth and the transition to an economy based on the efficient use of resources the European Union considers crucial the achievement of targets like the reduction of the energy

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use, the reduction of CO_2 emissions and the increase of renewable resources employment. The main energy policy tool is represented by the Climate and Energy Package 2020 (European commission, 2014).

In agriculture, protected crops is one of the sectors that mostly employ energy for heating. Protected crops also employs greenhouse structures to control and trap solar radiation and create ideal conditions for the plant growth. Under the technological point of view, greenhouses can be classified into three groups (DPI, 2007): low technology greenhouses (LTG) with a relative simple structure, a minimum or absent climate control system; medium technology greenhouses (MTG) with an iron based structure and a cover made of rigid materials (glass or plastics) and an heating system; high technology greenhouses (HTG) with a structure in galvanized steel and covered with glass, provided of cooling/heating systems for air and substrate conditioning and forced ventilation.

The classification of greenhouses can be made upon different criteria, for example size and shape of the structure. In the Mediterranean European area, the main types are: tunnels, greenhouses with curved roof and pitched roof greenhouses. In general terms the height of these structures do not exceed six meters. On the contrary in the Northern European countries the height is over five meters (Campiotti, 2013).

The climate control is an established practice in the Central and Northern regions of Italy. Many authors analysed the energy demand for greenhouse heating. For Italy, it was reported (Bianchi, 1985) an energy consumption for the period between December and March (350 h) of about 0.26 kWh/m^2*h. As reported by Campiotti (Campiotti et al. 2013) these results are consistent with others found in literature for France (Chiapale et al. 1980) but only if we consider a temperature gradient between greenhouse and environment of 20 °C.

The modelling of the energy demand of greenhouse heating can be made in last approximation taking into account the thermal characteristic of the cover material and the gap between the optimal temperature for the protected crop and the environmental temperature. To this aim the model reported by Campiotti (Campiotti 2013) has been considered.

The aim of this study is to give a primary evaluation of the energy consumption of greenhouses for the Ancona district. The goal of the study is to give useful information to the policy maker for a correct incentivization of greenhouse production by providing data of energy consumption more linked to the real greenhouse system employed in the region. The results of this study could support the creation of a more virtuous production chain and could support regional policies also on energy use efficiency and GHG emissions reduction.

2. Material and Methods

The original sample of Small and Medium Enterprises (SME) in the Ancona district involved in nursery productions consists of 62 units. A large amount of information was collected but not always complete. More in detail, based on the obtained information, three typologies of greenhouse were individuated regarding bearing structure, eighteen types of cover considering the material used and five typologies of fuels/biofuels or a mix of them (Table 1). Regarding the structure typology, the greenhouses have been grouped into three basic types and three derived types. About the cover typology, the greenhouses can be grouped into 10 different categories and 8 categories for plastic films, semi-rigid laminates and rigid sheets. Finally, we considered five different categories with respect to the fuel used.

A further analysis was carried out on a subsample of 16 enterprises located in different parts of the district as reported in the Figure 1. The selection was based on the completeness of information. Together with the enterprises' locations the authors selected five representative weather stations to collect local climatic data.

Additional information provided by the district's administrative offices, are about the volume of heated greenhouse for each company, the amount of fuel given to each company and the predicted months of usage.

All this data has been used as input for the model reported by Campiotti (Campiotti 2013). This model is useful to predict the energy demand of each company. The model selected is:

$$E = \left(\frac{Ac}{Ag}\right) * U * (Ti - Te) * h * \eta$$

where

E is the energy (kWh) necessary to overcome the minimum thermal exigence of the crop,

Ac (m^2) is the total exchange surface of the greenhouse (roof, walls and fronts),

Ag (m^2) is the projected surface of the greenhouse to the soil surface,

U ($W*m^{-2}*K^{-1}$) is the universal thermal exchange coefficient,

Ti (K) is the minimum internal temperature,

Te (K) is the external environmental temperature,

h (hours) is the time of use,

η is the performance coefficient.

Due to the absence of some essential information some should be estimated. The information relative to the Ac is missed but we know exactly the value of Ag.

Table 1: Type of greenhouse structure, cover and fuel employed in the sample selected and the original sample of enterprises.

Greenhouse type		*Cover type*		*Fuel type*	
Type code	*Description*	*Type code*	*Description*	*Type code*	*Description*
1	*Tunnels without vertical walls*	***1***	***Glass***	*1*	*Diesel*
2	*Tunnels with vertical walls*	***2***	***Plastic films***	*2*	*Pellet*
3	*Greeenhouses with flat piched roof*	*2A*	*Polyetylene (PE)*	*3*	*Pellet/Kernel + Diesel*
4	*Type 1+2*	*2B*	*Polyvinyl chloride (PVC)*	*4*	*Pellet + Diesel*
5	*Type 1+3*	*2C*	*Ethyl vinyl acetate (EVA)*	*5*	*Diesel + Methane*
6	*Type 2+3*	***3***	***Semi-rigid laminates***		
		3A	*Polyester and PRFV*		
		3B	*Polyvinyl chloride (PVC)*		
		3C	*Polymethyl methacrylate (PMMA)*		
		4	***Rigid sheets***		
		4A	*Polycarbonate (PC)*		
		4B	*Polymethyl methacrylate (PMMA)*		
		5	*Nylon film + semi-rigid PVC laminates*		
		6	*PE + PRFV*		
		7	*PE + PC*		
		8	*Nylon (polyammides)*		
		9	*PE + EVA*		
		10	*PE + semi-rigid PVC laminates*		

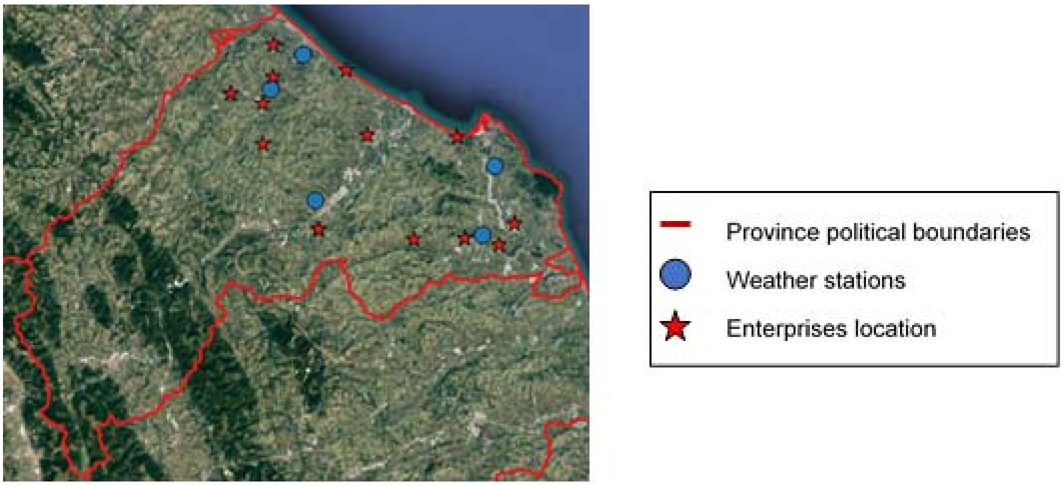

Figure 1: Map of the selected enterprises' locations and of the weather stations of Ancona district.

The ratio Ac/Ag vary between 1.5 and 1.8 for the greenhouses in the considered climatic area. In this specific case, the value of Ac/Ag was set at 1.65 and the value of Ac calculated upon this. The value of U was set at 8.3 that corresponds to the value for greenhouses covered with plastic materials (plastic films) and with ambient condition of no or slow wind. Ti was declared by the enterprises or calculated considering the species cultivated for the specific period. Te was collected from the service SIRMIP On Line (SOL) of the Marche region considering the weather stations as reported in Figure 1. The calculation approach was focused to define for each company the moments in which the external temperature was lower than the internal one. The sampling time of temperature (Te) considered was 0.5 h. The reference period is the autumn, winter and spring between 2014-2015. This data determinate also the total hours of use. Each temperature measurement (Te) was compared with the relative Ti. The time value h considered for each comparison was thus 0.5 h.
Although some of the contacted enterprises gave a specific performance coefficient (η), no one of the 16 selected enterprises did, so the value was set to 0.9. This choice was made also because the declared performance coefficients are all between 0.88 and 0.91.

3. Results

The results of the analysis carried out on the subsample of 16 enterprises are reported in Table 2. Regarding the type of structure, the most represented type of greenhouse is the tunnel code 4 and code 2. These typologies represent the 56 % of the sample. The less represented type is the number 5.
Plastic materials are the most used for cover representing the 76 % of all the materials employed. The most used fuel for heating is diesel (in 84 % of enterprises). The covered surface varies between 0.004ha and 4ha and 89 % of nurseries have a covered area smaller than 1ha (mean 0.2 ha). The average heating power installed for diesel systems is about 250 kW, with about 59 l/day of fuel combusted.
Considering the cover material, the most used is the plastic film category (code 2, 69 %) and inside this group the most represented is the type 2A (Polyethylene, 45 %).
Regarding the fuel type used the most represented is type 1 (75 %) and type 3 (13 %).

Table 2: Characterization of the companies considered.

Company code	Greenhouse type	Cover type	Fuel type	Heated surface[1] (m^2)	Installed power[1] (kW)	Diesel consumed[1] (kg/y)	Usage (h)[1]	Internal temperature (Ti)[2] T min (°C)	Internal temperature (Ti)[2] T max (°C)
11	6	2B	1	2,800	700	6,150	1,092	6	15
31	4	2	1	610	134	4,100	1,512	10	10
1	2	2A	3	2,500	698	106,618	1,884	2	16
3	2	5	5	2,500	759	51,250	1,536	5	8
27	4	2B	4	1,900	490	45,000	1,500	7	8
35	6	3B	1	750	332	12,300	1,452	2	11
8	2	2C	1	800	138	4,100	984	8	10
33	4	2A	1	1,380	352	11,047	1,452	5	16
32	5	7	1	1,600	419	10,000	3,420	18	18
5	2	2A	3	2,895	476	21,630	564	8	10
15	1	2A	1	5,560	296	3,157	540	8	9
17	1	2C	1	1,800	228	7,823	636	2	8
19	1	2C	1	735	279	2,952	1,140	7	7
34	6	10	1	600	70	8,200	864	10	10
28	4	9	1	2,500	349	1,920	240	2	3
29	4	2A	1	2,230	92	3,104	396	2	3

[1] declared by the companies; [2] where Tmin and Tmax are the same there is only one temperature requirement.

The Figure 2 shows the energy used for heating during the whole cultivation cycle compared with the energy used calculated based on official information. About the 66% of enterprises show an average official energy consumption above the calculated average energy consumption. Differences in some cases are very evident. For example, enterprise with code 1 shows an official energy consumption about four times higher than the average calculated consumption. Other enterprises (code 11, 33, 32, 5) show an official energy consumption lower than the calculated average consumption. Maximum and minimum values are very variable for the enterprises dealing with several protected crops with very different temperature requirements. In general terms, it can be noticed that the total assigned diesel amount is consistently higher than the average estimated diesel amount.

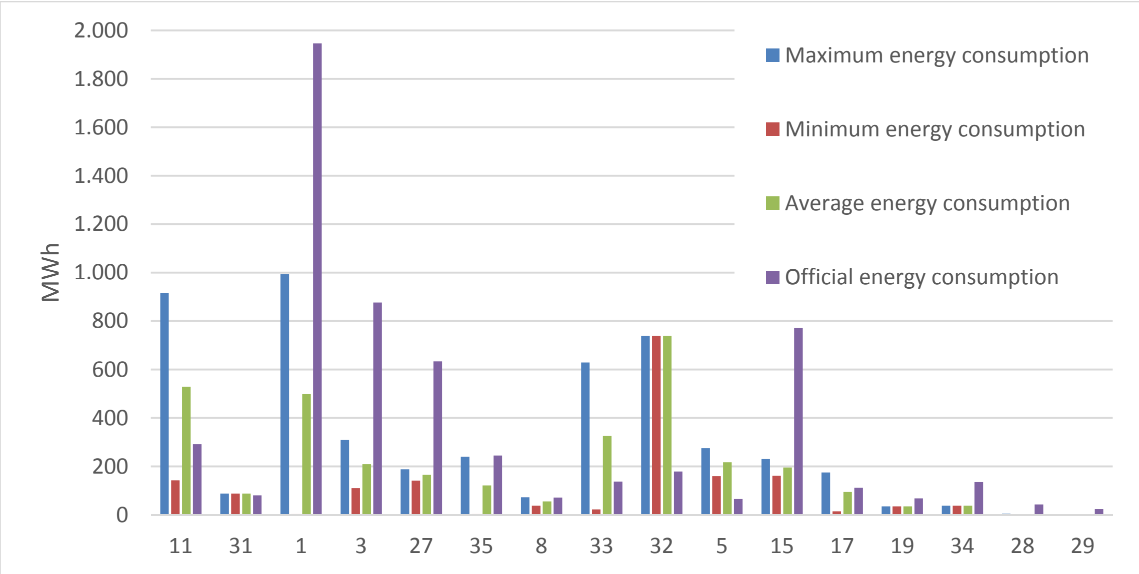

Figure 2: Comparison between energy consumption based on official information (kWh used) and energy consumption based on own calculation.

From the results, it can be calculated that the range of the kilograms of diesel per square meter assigned is varying from 1 to 66, so extremely variable.

4. Conclusions

The study highlights that in general terms average official diesel assigned to the enterprises for protected crop incentivization, exceeds the calculated value based on technical and environmental parameters. Nevertheless, the methodology used to calculate the assigned amount is probably based on the volumes of greenhouses declared by the enterprises, so it doesn't take into direct consideration the actual external temperature and the thermal exigence of the different crops.

The simple model proposed is a good compromise between complexity and completeness. This model could be useful especially if its application is repeated in different years to take into account climate variability and to guarantee for a more consistent diesel assignment. The increased information could be also useful to refine the model by including specific data regarding for example materials, shape, real thermal exchange surface. This study was also useful to emphasize some critical points that should be considered for the foreseeing of energy consumption and needs of nursery compartment. The results of this study could support the creation of a more virtuous production chain and could support regional policies also on energy use efficiency and GHG emissions reduction because at present the current assignments is not linked to these aspects. It can be worthy to be noticed that the climate change can affect the seasonal external temperature and the greenhouse energy requirements could be decreased in the mid and long term. In this scenario it is not useful to employ a rigid system for the assignment of diesel and these kind of studies can provide information to improve the system.

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Agriculture, forestry and fishery service, Marche region, Via Gentile da Fabriano, 9 Ancona, Italy

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