Monitoring Energy Consumption in Belgian Glasshouse Horticulture

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ABSTRACT

Energy consumption and energy efficiency are topical matters in the Belgian glasshouse horticulture. In Belgium only a few data on energy consumption in the agricultural and horticultural sector are available. To fill this gap of information, the Centre of Agricultural Economics developed an extrapolation model that uses data from the Farm Accountancy Data Network of the Centre and data of the Agricultural Census of the National Institute of Statistics to monitor the energy consumption in the glasshouse horticultural sector from 1980 till now. The model is developed in such way that for each holding of the population the energy consumption is estimated. This allows us to estimate the energy consumption for different aggregates. The estimation of the share of the different energy sources in the total energy consumption makes it possible to estimate emissions due to the heating of the glasshouses. On the other hand the model creates an instrument for researchers and policy makers to evaluate the impact of energy saving actions on the energy consumption of the glasshouse horticultural sector.

keywords: Monitoring, Energy consumption, Modelling, Emission, Energy efficiency

INTRODUCTION

In the past few years the agricultural and horticultural sector became more conscious that production methods have to be ecological to the environment. Although the agricultural sector already produces biofuels on a rather limited scale (biofuels, biogases, etc.), the sector is still characterized by a high input of energy. In the more northern situated countries, the well-developed glasshouse horticultural sector represents a relative large part of the total energy consumption. For environmental and economical reasons, there is aimed for a more rational use of energy. The natural fossil fuel reserves are not inexhaustible and the emissions of CO_2 and other greenhouse gasses, released by the combustion of fossil fuels, contribute to pollution of the environment. On the other hand, the severe competition of the fast developing horticultural sector in the southern situated countries, with less energy demanding production systems, puts a high pressure on the profitability of northern horticultural holdings (Taragola and Van Lierde, 1996; Verhaegh, 1998).

So, on the threshold of the Third Millennium, energy saving and a more rational use of energy are topical matters also in the horticultural production. Efforts are made to restrict the energy use by developing new production methods and by actions for greater penetration of alternative energy sources in horticulture (use of waste energy from industry, co-generation of heat and electricity, residual heat, ...). To carry out a good energy policy, a clear insight into the actual energy consumption, the evolution of this energy consumption and the evolution of the energy efficiency is necessary. In this paper an extrapolation model developed by the Centre of Agricultural Economics is presented. The model serves as a tool for monitoring the energy consumption in the glasshouse horticulture from 1980 till now. It is constructed in such way that it creates a large base for further research. The first results of the model are briefly discussed.

OBJECTIVES

A good energy policy in the glasshouse horticulture asks for a clear insight into the energy consumption of the sector. The required information especially concerns:

- the total energy consumption of the sector,
- the energy consumption per subsector (vegetables, ornamental plants, etc...),
- the evolution of the energy consumption over the years,

- the regional distribution of the energy consumption,
- the distribution of the energy consumption over the individual holdings,
- the percentages of the different kinds of energy sources in the total energy consumption.

These requirements were taken into account when developing the extrapolation model. The individual approach in the model creates the possibility to estimate the energy consumption in the glasshouse horticultural sector for different aggregates, e.g. regional aggregates, subsector aggregates, aggregates according to the cropping plan, holding size, etc.... The estimation of the share of the different energy sources in the total energy consumption makes it possible to evaluate the direct effect on the environment by calculating emissions.

METHODOLOGY

Data Sources

In Belgium, in contrast with other countries, only a few data are available on energy consumption in the agricultural and horticultural sector. In the Netherlands, where the glasshouses are mainly heated with natural gas, data on the energy consumption at Dutch horticultural holdings can be obtained from statistics of the N.V. Nederlandse Gasunie completed with data from the economic accounts of the greenhouse horticulture from the LEI-DLO (Van der Velden et al., 1996). In Belgium no global figures of the energy consumption in the horticultural sector are available.

The model developed to estimate the energy consumption in the Belgian glasshouse horticulture is based on data gathered in the Farm Accountancy Data Network (FADN) of the Centre of Agricultural Economics (C.A.E.) and data of the yearly Agricultural Census organized by the National Institute of Statistics (N.I.S.). Since 1980, the Belgian FADN of the C.A.E. registers more than financial data alone. The information on the costs of the energy consumption is completed with information on quantities of the most important energy sources used at the horticultural holdings.

The yearly Agricultural Census of the N.I.S., on the other hand, gives information on the structural characteristic of each agricultural and horticultural holding with a commercial activity in Belgium. For each holding in Belgium, for instance, the area of crops cultivated under glass is known.

The model makes it possible to extrapolate the energy consumption data of the FADN to the whole Belgian glasshouse horticultural population using the data of the yearly Agricultural Census.

Extrapolation Model

The extrapolation model for the energy consumption is partly based on an existing extrapolation model used to extrapolate economical characteristics to the horticultural population (Mineur and Van Lierde, 1991). The observation field and the sample are divided in a number of aggregates based on the holding type and the economical dimension of the holding (measured in Standard Gross Margin or SGM). This extrapolation model is adapted to be used for the estimation of the energy consumption in glasshouse horticulture (Fig. 1).

The total energy consumption in glasshouse horticulture not only depends on the area under glass that is heated but also on the heating intensity, mainly determined by the cropping plan. In the FADN, the cropping plan of the holdings for a whole year is known. In the yearly Agricultural Census, only information on the kinds of crops that are present in the greenhouses on May the 15th is known. To know the cropping plan of the holdings of the population for the whole year an estimation of the cropping plan is made based on experience and knowledge available in the section of 'Horticultural research' of the C.A.E. and the situation on May the 15th. For example, for a holding that mentions in the census a cultivation of tomatoes on substrate there can be supposed that this cultivation on substrate goes on during the whole year, or will be succeeded by a late cultivation of tomatoes or cucumber (when a substrate installation is present there are few other possibilities for the cropping plan).

Based on this information 12 cropping groups in total were aggregated, identifiable in the census as well as in the sample of the FADN. Each group gathers cropping plans with the same energy demand, for example a cropping group of vegetables cultivated on substrates, a cropping group of azaleas, ... The classification in cropping groups is mainly based on the typology of the holdings as used by the C.A.E. (Van Lierde, 1985). On the other hand data from the FADN show that at the bigger holdings, and especially in the sector of greenhouse vegetables, more energy consuming crops are cultivated than at smaller holdings.

So, 12 groups of crops were selected and as the intensity of heating also depends on the dimension of the holdings, the holdings were divided into five dimension groups according to the economical dimension of the holdings (measured in SGM). In total 60 energy coefficients (12 groups and 5 dimensions or 60 aggregation cells) are calculated to estimate the total fuel consumption of the holdings in the population.

Next, for each holding with glasshouses recorded in the census, the economical dimension of the holding is calculated and the glasshouse area of the holding is divided over the 12 cropping groups (for most of the holdings there is only an area for one group of crops). These areas are multiplied with the corresponding energy coefficients (corresponding with the dimension of the holding and the cropping group) and the sum gives the total fuel consumption for the holding. Notice that because average values are used, the variance of the coefficients in the aggregation cells is not taken into account.

To estimate the electricity necessary to run the heating system, a regression model was developed, expressing the relation between the total fuel consumption and the electricity necessary for the heating system. Based on this regression model, and as far as for each holding in the population the total fuel consumption for heating is estimated, the electricity consumption for the heating system can be estimated and added to the fuel consumption to calculate the total energy consumption of the holding. The total energy consumption of a holding is expressed as primary energy. The primary energy of the electricity is calculated by converting the amount of used electricity to the amount of primary energy necessary at the Belgian power stations to produce this electricity.

Besides the energy coefficients for the total fuel consumption, energy coefficients per energy source are determined based on the FADN data (heavy fuel oil, light fuel oil, natural gas, coal, etc...). These energy coefficients make it possible to estimate the share of the different energy sources in the total energy consumption of the population. Since these coefficients are averages per aggregation cell, the results for the individual holdings are less precise. They have only a sense after the summation for aggregates.

RESULTS AND DISCUSSION

Energy Consumption at glasshouse horticultural holdings

The estimation of the total energy consumption by means of the extrapolation model is based on the estimate of the energy consumption for each individual holding in the population. This makes it possible to combine the energy consumption for different aggregates, e.g. subsector aggregates and regional aggregates.

In figure 2 the total energy consumption for the Belgian glasshouse horticulture and its subsectors according to the model is given. For the studied period the total energy (including electricity) used to heat Belgian glasshouses, expressed as primary energy, increased from 14.687 PJ in 1980 to 22.990 PJ in 1997. The primary energy consumption in the glasshouse horticultural sector represented in 1980 0.7 % of the total primary energy consumption in Belgium, in 1996 this increased to 1.0 % (Van Lierde and De Cock, 1999). The most energy consuming subsector is the sector of the glasshouse vegetables, consuming almost 70% of the total primary energy of the glasshouse horticultural sector. From 1980 till 1997, the energy consumption of the glasshouse vegetables is more than doubled, while the energy consumption of the ornamental plants under glass hardly increased.

While the total energy consumption during the period of 1980-1997 increased with 57%, the total area of the glasshouse horticultural production increased only with 22%, from 1683 ha in 1980 to 2048 ha in 1997. This means that the intensity of the energy consumption in the glasshouse horticultural sector strongly increases. The increase is completely attributable to the development of the energy intensity of the glasshouse vegetables (Van Lierde and De Cock, 1999). This is not so much because more energy was used in a particular crop, but because of a shift in crop selection to more energy intensive crops, especially the introduction and the expansion of the hydroponic cultivation.

Further examination of the energy intensity shows that the yearly used energy per square metre of glass area depends on the fuel price and the differences in outside temperatures. So, the energy intensity in the glasshouse horticultural sector was lowered during the energy crisis of the early eighties due to high energy prices. Based on data from the extrapolation model, a regression model (1) was build that shows that 96% (R) of the yearly differences in energy consumption per square metre glass area can be explained by differences in the real fuel price (1997=100) and differences in weather conditions, expressed in number of day degrees (Van Lierde and De Cock, 1999):

$$Consumption = 631 - 1499\ price + 0.2058\ degrees \qquad (1)$$

with: *consumption*, the energy consumption expressed in Megajoule useful energy per m ; *price*, the energy price expressed in Belgian francs per Megajoule useful energy (price index=1997, the average price payed at horticultural holdings in 1997=0.145 BF/MJ useful energy) and *degrees*, the number of day degrees 18°C (normal year=3015).

The regression model therefore makes it possible to give an indication of a possible effect of a price policy on the consumption of energy and to correct the total energy consumption for differences in average outside temperatures during consecutive years. The correction for differences in outside temperatures allows us better to compare the energy consumption during consecutive years, without the influences of differences in outside temperatures.

The individual estimates of the energy consumption of each holding with crops under glass, makes it possible to get an idea on the distribution of the energy consumption over the different holdings and the regional spreading of the energy consumption. The distribution of the energy consumption over the different holdings shows that the energy consumption is strongly concentrated on a restricted number of holdings with a high consumption of energy. More than half of the energy consumption is used by only 10% of the holdings. Twenty percent of the holdings consume almost 75% of the total energy of the sector and represent together almost half the cultivated area under glass. During the whole period of 1980-1997 the calculated Gini-coefficient, as an indicator of inequality in distribution, fluctuates around the same value. This means that no changes in the concentration of the energy consumption occurred. The aggregation of the energy consumption per region shows that energy consumption is much more intense in regions where glasshouse vegetables are important than in those regions where ornamental plants under glass are important. This is valuable information for the government. To carry out an efficient energy policy it is recommended that the government focuses its energy saving actions on a restricted number of holdings namely those holdings who use most of the energy or on those regions with the highest concentrations of energy consumption and with this also the highest emissions. This is much more efficient than measures for the whole horticultural sector. The model we propose allows us to identify these holdings.

Emission of CO_2

The estimation of the share of the different energy sources in the total energy consumption gives the possibility to calculate the CO_2 emission and the emissions of other pollutants. In this way we can evaluate the direct effect of the energy consumption on the environment. The total emission of CO_2 is determined by the area under glass that is heated, the energy intensity and the kind of fuel used. The most important energy source used in Belgium for heating glasshouses is heavy fuel oil. In 1997 63% of the total primary energy was delivered by heavy fuel oil, 13% by light fuel oil, 15.5 % by natural gas and 3.5 % by coal. Only during the energy crisis the heavy fuel oil was mainly substituted by coal. During this period the price evolution of coal was better than that of the other fuels. In 1985 only 32% of the primary energy was delivered by heavy fuel oil but 48% was delivered by coal. As the emission of CO_2 per unit primary energy for coal is higher than for the other fuels (IPCC, 1996) this conversion was negative for the environment. After the energy crisis the price of heavy fuel oil declined and coal was substituted again by heavy fuel oil.

Nevertheless, the use of heavy fuel oil also puts a heavy load on the environment. In 1997 the emission of CO_2 by the energy consumption in the Belgian glasshouse horticulture was estimated on 1.6 million tons of CO_2. This is 57% more than in 1980 and corresponds with an emission of 78 kg CO_2 per square metre glass area. A decrease in the emission of CO_2 by the glasshouse horticultural sector can be obtained by lowering the energy consumption per square metre or by using other energy sources more ecological to the environment. The last few years, because of the more severe environmental legislations, natural gas becomes more and more important in the Belgian glasshouse horticultural sector and the use of coal declines. This has a positive effect on the environment. In relation to the base year for CO_2 equivalent emissions of greenhouse gases 1990 (EMIS, 1999), the CO_2 emission per square metre glass area in the Belgian glasshouse horticulture decreased in 1997 with approximately 11%. The total emission of CO_2 in 1997 only decreased with 1% due to an increase of the glass area. But from 1991 on, the total emission of CO_2 yearly declines. From the model could be calculated that if, from now on, all the glasshouse horticultural holdings would change to natural gas, the total CO_2-emission could be decreased with 30%. At the moment, however, natural gas is still more expensive compared with heavy fuel oil and not available for each holding.

Possibilities for further research

A first step in further research, is the calculation of the energy efficiency in the Belgian glasshouse horticulture. Because the choice of an energy efficiency indicator is dependent on the vision someone has on what an efficient use of energy is, the energy efficiency will be evaluated in different ways. Besides the physical energy efficiency that calculates the energy consumption per unit of horticultural product, also the economical energy efficiency or the ratio of the energy costs and production value will be studied (De Cock and Van Lierde, 1998).

The possibility of calculating and evaluating energy consumption, emissions and energy efficiency of the Belgian glasshouse horticulture by means of the model results in a clear insight in the energy consumption of the sector and creates a large base for further research. The individual approach of the model allows us to make simulations in which hypotheses can be tested. The aggregation of individual holdings with the highest energy consumption can be determined as target group for energy-saving actions. The effect of investments in energysaving measures, the use of more environmental friendly fuels as natural gas and the introduction of new technologies in the field of energy (heat/power stations, waste energy, etc...) at these holdings can be quantified for the energy consumption, the energy efficiency and the emissions for the whole glasshouse horticultural sector. Since the model developed to estimate the energy consumption is connected to the FADN where also the economical aspects of the holdings are registered, the economical aspects of the energy consumption and the energy costs can be studied.

At the moment, the model is only developed to estimate the energy consumption for heating glasshouses in the horticultural sector. Further adaptation of the model should allow us to estimate the total energy consumption in the whole horticultural sector as well as in the agricultural sector. The data necessary for this research are already available in the FADN of the C.A.E..

CONCLUSIONS

Energy data for the whole horticultural and agricultural sector are very scarce in Belgium. On the other hand, the holdings of the FADN of the C.A.E. are good representatives of the Belgian agricultural and horticultural sector. For many years data on energy consumption of these holdings are collected. The model allows to extrapolate these data to the whole population using data of the N.I.S. and is at the moment the only source of information on the energy consumption in Belgian glasshouse horticulture.

The developed model also creates an instrument for researchers and policy makers to evaluate the impact of their actions on the energy consumption of the whole glasshouse horticultural sector. This has to give enough indications to direct the energy policy and to define goal-directed actions in a more efficient way. Therefore the developed model and the further extension of the model to the whole horticultural and agricultural sector can be of great value for further energy technological research in this sector.

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National Agricultural Census

For every holding in the census determine:

- Area of cropping groups (12 possible groups)

- Dimesion class (SGM) (5 possible dimensions d)

National FADN

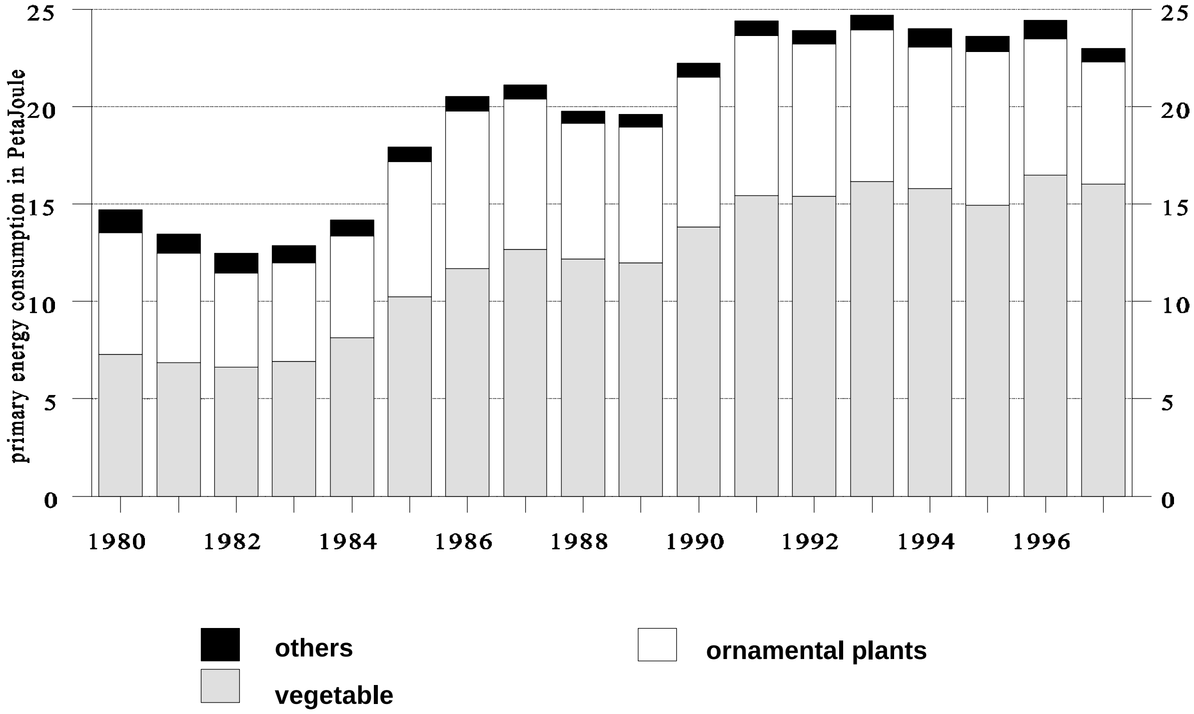
Determine energy consumption coefficients (MJ/m):

area per group and per dimension class		Coefficient energy use /m per group and per dimension class
A1d	*	C1d
A2d	*	C2d
.	.	.
.	.	.
.	.	.
A12d	*	C12d

Energy consumption of holding i with dimensions d (ECi):

ECi = A1D*C1d + A2d*C2d + ...+ A12d*C12d

Figure 1. Extrapolation model for determining the energy consumption in Belgium glasshouse horticulture



Source : C.A.E.

Figure 2. Evolution of the total primary energy consumption in the Belgian glasshouse horticultural sector and subsectors (vegetables, ornamental plants and others)