Calculating CO_2 footprint of the organic greenhouse horticulture

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Abstract

In recent years the horticultural sector has been confronted with questions about the carbon footprint of its products. However, the global standards used to calculate the greenhouse gas (GHG) emissions have some gaps that do not address the sector specific issues for horticulture, such as crop rotation, land use of soil organic matter and Combined Heat and Power (CHP). Therefore, a need was identified for a sector specific standard which addresses these interpretations gaps. In response to this need the `Carbon footprinting of horticulture products protocol` (DNCF2009) was developed by the Dutch horticultural sector. The protocol is intended to follow the guidelines of PAS 2050 for the life cycle analysis of horticultural products; a lot of situations in greenhouse horticulture has to be described in so-called Best Practices. In the greenhouse cultures energy consumption is the main component of the CO_2 emission. To save energy a lot of Dutch greenhouse companies use CHP to heat their greenhouses. These growers for example sell the superfluous electricity produced by the CHP to the national grid. The grower thereby generates two products; the horticultural product, says a tomato, and the electricity. The CO_2 emission of the electricity production should be deducted from the total CO_2 production of the CHP, in order to calculate the CO_2 emission that should be assigned to the production of the tomatoes.

To find out what the position of the organic way of cropping will be, organic crop production is compared with regular cropping systems, with or without CHP. An example for organic grown tomatoes is worked out. It shows the specific organic input factors and their impact at the CO2 footprint.

INTRODUCTION

Global heating as a result of greenhouse gasses is a hot item. The environmental impact of the modern horticulture sector is nowadays a subject of an increasing interest of the community. Wholesalers, supermarkets and consumer organisations want insight in the GHG emission of their products, as well for the organic as the regular way of cropping. One of the potential indicators of the impact to global heating of products is the CO_2 footprint. The Carbon Trust, DEFRA and British Standard Institute have developed a protocol for the calculations of the CO_2 footprint, the so-called PAS 2050. This protocol is based on the methodology of the Life Cycle Assessment (LCA). In 2008 the Dutch Horticultural Board and the ministry of Agriculture, Nature and Food Quality decided to start a pilot project to build a model to calculate the CO_2 footprint. This model can be used by the members of the Dutch Horticultural Board, to calculate the CO2 footprint of their own production plant and can calculate the effects of changes in the production method. (http://www.tuinbouw.nl/artikel/co2-footprint-berekenen)

During this pilot, it became clear that the use of cogeneration for the production of heat as well as electricity, gives a reduction to the CO_2 emission and so to the CO_2 footprint. Growers use cogeneration to save costs and energy. In 2010, in Dutch greenhouse horticulture there was approximately 3.000 MW electric power of co generators installed at a surface of 10.500 ha. Their yearly electricity production is about 10 TWh. This electricity is partly used for artificial lighting, but the main part is delivered to the national grid. The heat is used for the heating of the greenhouse. This decentralised cogeneration of electricity at greenhouses has benefits compared to central electricity production at normal power stations, where most of the heat will be cooled and wasted. The organic crop has to compete with this modern way of cropping, as well on the level of material use as well on the level of economics. In this article will be described the allocation methods for CHP and in three cases three different cropping systems for tomato will be worked out.

MATERIAL AND METHOD

In this study is made use of the data standard of a regular tomato crop starting in the second half of December until the end of November. (Vermeulen, 2008). The organic grown tomato crop starts at the beginning of January and ends in December. The study compared the CO_2 footprint of a regular greenhouse plant with and without cogeneration with this organic crop. Cogeneration is used to save energy, by avoiding energy waste, especially heat, at the central electricity plants. The relevant data are showed in table 1.

In the situation with the CHP the grower generates two products; the horticultural product tomato and electricity. For assigning CO_2 emission from a central source to multiple objectives, three ranked methods can be distinguished (BSI 2008, BSI 2008 2):

1. System reduction,
2. System expanding
3. Economic allocation.

Ad 1. System reduction. The production process will be broken down in sub-processes: the electricity production and the heat production. For this case the allocation is based at energetic output. In the case of 40 % electric and 50 % thermal return of power, 1 m^3 natural gas, 31.65 MJ/m^3, produces 3.52 kWh electricity. With a total return of 90 % ((1:3.52):0.9) 0,284 m^3 gives 1 kWh electricity. In practice the electric return varies between 38 % and 42 % and the thermal return between 50 % and 55 %. So the CO_2 emission of the electricity part will be based on (40 %: (40 % + 50 %) * 0.284) = 0.126 m3 natural gas / kWh. In horticulture the CO_2 produced by the co generator is also used in the crop production process. This makes the above described allocation method not useful.

Ad 2. System expanding. This method is based on expanding the system to include the impact of displaced products. In the cogeneration case the avoided electricity production. This allocation method will be useful, as second possibility, in the co-generation cropping system (case).

Ad 3. Economic allocation.

This allocation method is based on the economic return of the electricity as well as the crop. If for example in a tomato crop the yearly returns are € 50.00 and the electricity returns are € 12.50, the share of the electricity in the gas consumption of the co generator will be 12.5/(50+12.5) = 20%. If you need 0.284 m3 gas to produce 1 kWh, the electricity part will be (20% * 0.284) 0.0568 m3. This method is very instable and will give different CO_2 footprints through and over the years with a comparable input of energy. Because System expanding can be used, PAS2050 doesn't allow using the economic allocation method.

Looking for the avoided electricity production, in this case of CHP, the time of production is important. In The Netherlands the source of electricity is different during the day and within a week. There is a base load of electricity production that is filled in with long stay power plants such as: coal or nuclear. But the daily fluctuation of the electricity consumption is mostly filled in with gas combusting power plants. All this production methods have there own CO_2 emission, as showed in table 2.

In the tomato case the co generator is used for two purposes: 1) production of heat and CO_2 for the production and 2) electricity as a co product not used for the production of tomatoes. The produced electricity is sold at the electricity market. The electricity market in The Netherlands is split up in two main parts: base and peak hours. The peak hours are the hours at Monday till Friday from 7 till 23 o'clock, the hours with the highest electricity consumption. The base hours are the other hours. Because the CO_2 demand is also at daytime, most of the tomato growers use the co generator at peak time. The heat will be used in the greenhouse or stored for the night in heat storage. Because of the CO_2 demand some growers also use the co generator in the weekends at daytime, especially in the summer. Electricity is sold to the national grid and heat is wasted.

Back to the question 'what is the avoided electricity?'. A panel of energy experts concluded that in The Netherlands electricity delivered in the peak hours avoids electricity made by a gas combusted power plant and in the base hours made by a coal combusted plant. In this case it is simplified by calculating with 2/7 by coal and 5/7 by gas produced electricity, based on the number of days with and without peak hours. The so calculated avoided CO_2 emission is set off against the CO_2 emission of the gas used by the co generator. In the situation in which is well know what the amount electricity is delivered in peak and base hours, the real distribution can be used.

In the regular and the organic crop without CHP the assignment will be simply, all the CO_2 emission will be on the account of the tomato production. For all the cases the emission will be calculated for 1.000 kg tomatoes delivered at the distribution centre.

The CO2 footprint looks for the effect on the GHG of use of all materials during the whole production. The life cycle start with the growing of young plants, the production at the greenhouse and ends with the transport to the DC. The main materials are energy; gas and electricity, fertilizers, pesticides, plastics, rock wool, peat, etc.. The materials of the greenhouse are not specified, but calculated in the overhead of 10 %.

RESULTS AND CONCLUSIONS

In the study the CO_2 emission of an organic tomato crop is compared with a regular tomato crop with and without the use of co generator for heating the greenhouse. The results are shown in figure 1. The CO_2 footprint of the organic crop is 19% higher than the regular crop without cogeneration and more than double of the crop with CHP.

The use of a co generator lowers the CO_2 emission of the crop with 50 %, due to the avoided production of electricity by power plants, while the consumption of gas with co generator will be almost 50 % higher. So the use of cogeneration has a positive impact at the CO_2 emission of the community. By using the heat and CO_2 in the production process, cogeneration results in energy saving also compared to a central electricity production plant. The lower production of the organic crop is the main reason for the higher CO_2 footprint. It's the organic grower who can decide to use cogeneration to lower his CO_2 footprint.

Figure 2 shows the components of the CO_2 footprint. The gas consumption is the greatest CO_2 emission component, organic 86 %, 85 % without CHP and 78 % with CHP of greenhouse tomato production. So energy saving and the use of green energy are the first topics to increase the CO_2 footprint of protected horticulture. The other components with a visible impact on the CO_2 footprint are the use of fertilizers and the transport of the products to the DC.

DISCUSSION

The organic greenhouse horticulture has to compete with a fast developing conventional greenhouse horticulture. The use of CHP in greenhouse horticulture is one of these developments. New energy systems are already developed or will be developed such as:

- Heat delivery by greenhouse growers to other companies,
- Heat delivery by greenhouse growers to other no greenhouse partners, such as schools, swimming pools, etc.
- CO_2 delivery by electricity or industrial plants to greenhouses
- Use of geothermal heat,
- Bio energy
- Fermentation

Growers, organic as well as regular, can make a choice out of these options and look for the effects on the CO_2 footprint. They have to become aware that the community and the wholesalers want insight in the production method of their suppliers and the impact of the production method at the global heating and environment. The CO_2 footprint can be one of the indicators.

The CHP case is one of the many possibilities to use cogeneration in the greenhouse horticulture. The potential CO_2 emission reduction depends on a lot of specific factors. The most important factors are: electric and heat return of the co generator, number of hours with cogeneration, kind of avoided electricity production, placed power in relation to the surface of the greenhouse and heat and CO_2 demand of the greenhouse. So with this CO_2 footprint method, there is an easy tool to help growers to calculate the CO_2 emission of there own crop and production method.

In this case study the use of the co generator is based at the heat and CO_2 demand of the crop, so there will be as the least possible waste of heat at the greenhouse plant. To realise the shown reduction of CO_2 emission, the investment and extra gas consumption have to be earned back with returns of the electricity sales. In 2008 with high prices for as well base as peak time electricity delivery a growers let run the co generator extra hours, to generate extra income. In 2010 with low electricity prices growers has to stop cogeneration because the extra gas consumption will not be paid back by the sale of electricity. To realise reduction of CO_2 emission with cogeneration in the horticulture, there need to be a stable electricity market with fair prices.

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Tables

Table 1. Input data tomato crop

		Organic[2)]	Regular [1)]	Regular [1)] with CHP
Production	kg/m^2/year	50	58.5	58.5
Electric power co generator	MW/ha			0.5
Cogeneration	hours/year			3565
Natural gas boiler	m^3/m^2/year	43.2	43.4	15.0
Natural gas co generator	m^3/m^2/year			49.7
Electricity	kWh/m^2/year	10	10	10
Electricity production	kWh/m^2/year			178
PE/PVC/PS	kg/ha/year	436	927	927
Pesticides	kg/ha/year		8	8

[1)] (Kwantitatieve Informatie voor de Glastuinbouw 2008, p88)

[2)] Estimated

Table 2. CO_2 emission of electricity production in the Netherlands (Groot&Vreede 2007, Seebregts & Volkers, 2005, Sevenster e.a. 2007).

	Kg CO_2 / kWh Excl. pre combustion
Nuclear	0
Natural gas average	450
Oil	660
Coal	870
Import in Holland 2006	586
Production average Holland 2006	543

Figures

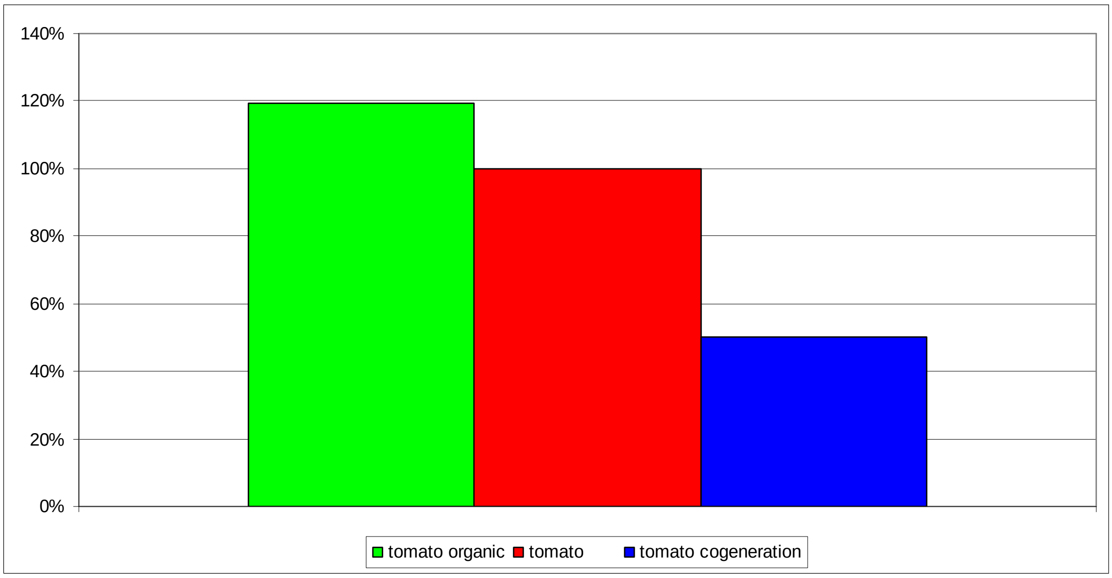

Figure 1: Tomato crop: the CO_2 emission (kg CO_2/ ton) of an organic crop and a regular crop with and without heating wit a co generator.

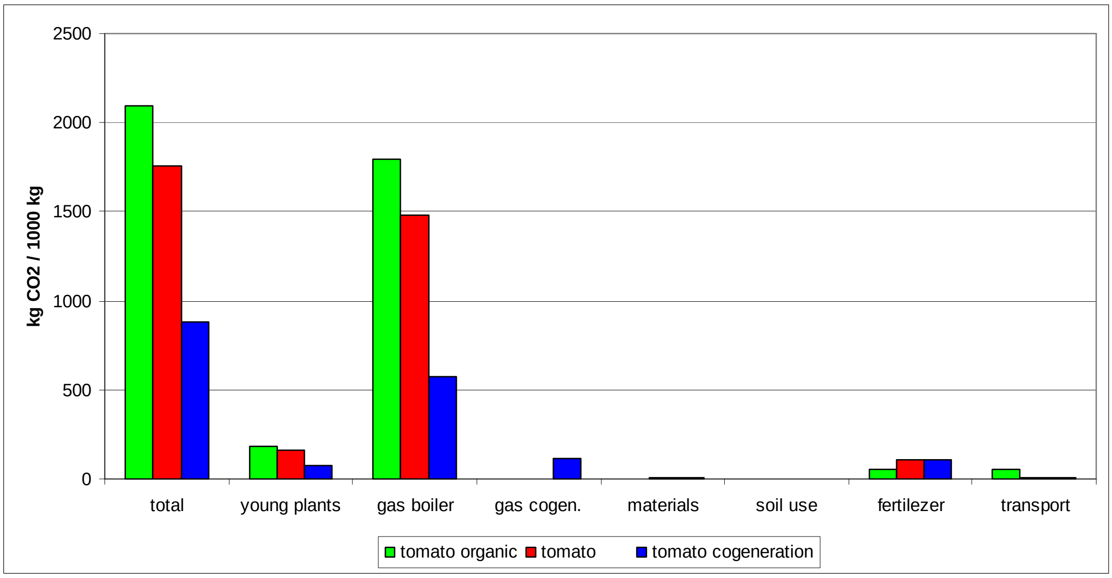

Figure 2: Tomato crop: total and components of the CO_2 emission (kg CO_2/ ton) of an organic crop and a regular crop with and without heating wit a co generator.