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Reducing CO_2 emissions through efficient use of energy in horticultural glasshouses

Depending on the technology used, the operational system and the crop being grown, around 500 000 kWh heating energy per year is required for a 1 000 m^2 ground area greenhouse. Reducing heat losses from such buildings is very important for increasing energy efficiency through less energy costs and CO_2 emissions. The installation of an energy shield is very efficient in this respect, offering energy savings of approx. 25 %. Further energy savings can be achieved with two-layer greenhouse walls and roof. Combining technical and management measures heating energy requirement for a 1 000 m^2 greenhouse can be reduced by up to 60 %. This could mean an around 124 t reduction in annual CO_2 emissions from a Venlo greenhouse with oil-fired heating. In that some of these energy saving actions also save operating costs, negative CO_2 reduction costs are achieved in most variants.

Keywords
Horticultural glasshouse production, energy saving, heat losses, energy costs

Abstract
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Cultivation under glass is characterised by a very high demand for heating energy and is one of the most energy-intensive production systems in agriculture and horticulture. At prevailing energy prices the heating costs in glasshouses equal between 7 and 12 % [1] of total production costs. This prompts glasshouse owners to reduce energy consumption, or to use the energy more efficiently. Insulation of the glasshouse walls and the installation of an energy shield provide a significant reduction in energy consumption and calculations show how these energy saving measures also contribute to reductions of climate damaging CO_2 emissions.

The work was supported through the Climate Protection Initiative of the Ministry of Food, Agriculture and Consumer Protection (BMELV) and the Ministry of Environment, Nature Protection and Reactor Security (BMU) and included in the "Guidelines for increasing energy efficiency in agriculture and horticulture" [2].

Under these guidelines are promoted cost intensive measures in agriculture and horticulture helping to reduce carbon dioxide emissions.

Reference procedures, calculation methods and assumptions

Using the example of an existing Venlo glasshouse with 1 000 m² area, on which modernisation measures for energy savings should be carried out, the following represents the calculation of the energy savings, the climate gas emissions and the emission reduction costs.
The comparatively small size was chosen since many of the glasshouses requiring modification fall within this size range. The efficiency of the measures was correlated to a constructional engineering reference [3]. The most important features are listed in **Table 1**.

In the calculations it was assumed that the yields and qualities as well as the monetary benefits do not change.

The calculated energy savings were made for heating based on oil or anthracite coal. For the price of the heating, 0.86 cent/ kWh for heating oil and 0.56 cent/kWh for anthracite coal were used as a basis [4]. The calculation of the efficiency of the heating was carried out using the HORTEX [5] programme. For the calculation, two different temperature requirements of the glasshouse crops were considered. Firstly a moderate temperature of 12–18 °C suitable for crops such as primroses, hydrangeas and poinsettias was used and secondly a warmer temperature of over 18 °C needed for orchids, begonias and tomatoes.

The energy cost savings are taken into account in the fixed costs of the modernisation investments and are shown in the tables as additional charges.

Table 1

Modernisation variants compared with reference greenhouse

Gewächshaushülle *Greenhouse walls and roof*	**Referenz** *Reference*	**Modernisierungsvarianten** *Modernisation variants*		
Dach *Roof*	Einfachglas *single glass*	Einfachglas *single glass*	Doppelfolie *dual plastic film*	Stegdreifachplatten *triple cross-braced panes*
Stehwand *Wall*	Einfachglas *single glass*	Stegdreifachplatten *triple cross-braced panes*	Doppelfolie *dual plastic film*	Stegdreifachplatten *triple cross-braced panes*
Energieschirm *Energy shield*	einlagig, gering aluminisiert *single layer, slightly aluminised*	zweilagig, stark aluminisiert *double layer, strongly aluminised*		

Table 2

Modernisation measures with temperate crop production. Greenhouse type: Venlo, 1 000 m² ground area, anthracite coal-fired heating (grey background) and oil-fired heating

Temperaturführung *Heating*	**Temperiert (12–18 °C)** *Temperate (12–18 °C)*			
Dach *Roof*		Doppelfolie *dual plastic film*	Stegdreifachplatten *triple cross-braced panes*	Stegdreifachplatten *triple cross-braced panes*
Stehwand *Wall*	Stegdreifachplatten *triple cross-braced panes*	Doppelfolie *dual plastic film*	Stegdreifachplatten *triple cross-braced panes*	Stegdreifachplatten *triple cross-braced panes*
Energieschirm *Energy shield*	zweilagig, stark aluminisiert *double layer, strongly aluminised*			
Investitionen [€] *Investment [€]*	63.505	82.155	146.555	146.555
Fixe Kosten [€/a] *Fixed costs [€/a]*	11.564	13.980	24.284	24.284
Energieeinsparung [%] *Energy saving [%]*	30	34	60	60
Einsparte Energiekosten [€/a] *Saved energy costs [€/a]*	12.259	14.026	24.603	16.366
Mehrkosten [€/a] *Additional costs [€/a]*	-695	-47	-319	7.917
Verminderte CO_2-Emissionen [t CO_2/a] *Reduced CO_2 emissions [t CO_2/a]*	38	44	77	97
Minderungskosten [€/t CO_2] *Costs of reduction [€/t CO_2]*	-18	-1	-4	82

For the calculation of the CO_2 emissions from the reference glasshouse and from the modernised variants, the emissions from the heating and from the heating distribution (electricity) are estimated. The specific CO_2 emissions from the German electricity mix in 2009 were 575 g CO_2/kWh_{el} [6].

The emissions from heating oil and anthracite coal used are estimated as 268 and 341 g CO_2/kWh_{th} respectively [7]. Only the energy expenses that arise from the provision and use of energy sources were assessed. Previous inputs such as the energy requirement for the production of building elements and their construction were not considered.

Results

For the given example the investments for the installation of triple-layer sheets in the roof and in the walls amount to ca. 147,000 € **(Table 2)**. The yearly fixed costs for this investment are ca. 24,000 €. Resulting from the 60 % reduction in heat losses, the horticulture firm requires ca. 250,000 KWh_{th}/year less heat energy for the temperate crop management. If the savings in operating costs (energy costs) are reckoned with the fixed costs, this gives a negative additional cost amounting to -319 € per year. With this increase in efficiency the heating with oil results in a reduction of ca. 77 t CO_2 emissions per year. This gives a cost reduction of -4 €/t CO_2.

For the other two methods with triple-layer sheets in the walls or the installation of double film in the walls and roof, the emission reductions are less because the conversion measures provide lower savings in energy. With these two options there are also cost reductions which means that the energy cost savings are higher than the fixed costs. Heating with anthracite coal results in higher additional costs than with heating oil because the energy cost savings are less. In comparison with oil fired heating the energy costs are only reduced by 16,000 €. The additional costs here are ca. 8,000 € which explains the higher costs of reduction .

Table 3

Modernisation methods with crop production at warmer temperatures. Greenhouse type: Venlo, 1 000 m² ground area, anthracite coal-fired heating (grey background) and oil-fired heating

Temperaturführung *Heating*	**Warm (> 18 °C)** *Warm (> 18 °C)*			
Dach *Roof*		Doppelfolie *dual plastic film*	Stegdreifachplatten *triple cross-braced panes*	Stegdreifachplatten *triple cross-braced panes*
Stehwand *Wall*	Stegdreifachplatten *triple cross-braced panes*	Doppelfolie *dual plastic film*	Stegdreifachplatten *triple cross-braced panes*	Stegdreifachplatten *triple cross-braced panes*
Energieschirm *Energy shield*	zweilagig, stark aluminisiert *double layer, strongly aluminised*			
Investitionen [€] *Investment [€]*	63.505	82.155	146.555	146.555
Fixe Kosten [€/a] *Fixed costs [€/a]*	11.564	13.980	24.284	24.284
Energieeinsparung [%] *Energy saving [%]*	30	38	59	59
Einsparte Energiekosten [€/a] *Saved energy costs [€/a]*	20.179	25.832	39.810	26.482
Mehrkosten [€/a] *Additional costs [€/a]*	-8.615	-11.852	-15.527	-2.199
Verminderte CO_2-Emissionen [t CO_2/a] *Reduced CO_2 emissions [t CO_2/a]*	63	81	124	157
Minderungskosten [€/t CO_2] *Costs of reduction [€/t CO_2]*	-137	-147	-125	-14

The reduction in CO_2 emissions increases from 77 to 97 t CO_2 per year since anthracite coal has a higher emission factor.

At the higher temperature cultivation, the saved energy and the CO_2 reduction is higher due to the increased requirement for heat energy. The modernisation variants with triple-layer sheets increase the reduction in CO_2 emissions from 77 to 124 t per year. For heating with anthracite coal, the cost reductions are negative due to the influence of the high energy savings.

Conclusions

The modernisation measures for energy savings with regard to costs, CO_2 emissions and CO_2 reduction costs were analysed for a Venlo glasshouse with 1000 m² cultivation area.

At temperate and warmer temperature regimes a 30 to 60 % heat energy savings potential, dependant on the modernisation measures, is feasible.

Up to 124 t CO_2 emissions per year can be saved with oil-fired heating and 157 t CO_2 emissions with anthracite coal-fired heating.

The cost savings for the presented variants with oil-fired heating are negative since the saved energy costs are higher than the fixed costs. For the variants with anthracite coal-fired heating only the cost reductions at warmer crop cultivation are negative since, due to the higher energy requirement, correspondingly high heat energy costs can be saved.

If anthracite coal is used as energy source the profitability resulting from the lower heating price is less for all variants, but due to the higher emission factor of the energy source the highest potential for reduction of emissions exists.

For all variants the economics of the measures for increased efficiency of heat energy will be strongly influenced by the amount of heat energy needed for the crop and by the energy source used.

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