WAGENINGEN UR
For quality of life

Design of a NIR-concentrator System Integrated in a Greenhouse

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Challenge

- Greenhouses are basically a solar collector of 10,000 ha.
- The incident solar energy is more than needed for the greenhouse energy consumption.

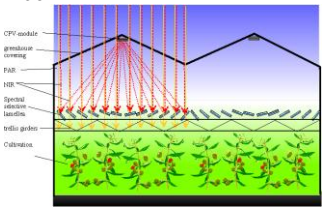

Fig. 1 Working principle of the lamellae greenhouse: the lamellae performed as a Fresnel mirror and reflect the direct solar Near Infrared Radiation (NIR) onto the PV-module. (visible light ⟶ and NIR radiation ⟶)

- Thermal radiation (NIR) is not necessary for plant growth but contains almost 50% of the incident solar energy.
- Possible contribution to sustainable energy supply is about: 15-25%

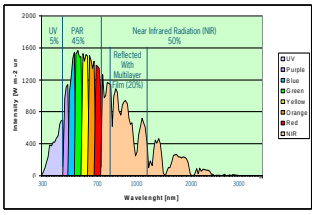

Fig. 2 The AM 1.5 Solar radiation. Radiation between 800 – 1200 nm is reflected by the multilayer film on the lamellae.

Approach

1. Separation of visible light (PAR 400-750 nm wavelength) and radiant heat (NIR 750 - 2500nm)
2. Concentration of radiant heat with a light transparent (PAR) mirror.
3. Conversion to electrical energy with PV-cells.
4. Integration of the solar Energy system in a greenhouse

The AM 1.5 Solar spectrum with the visible and NIR part is given in Figure 2. The wavelength area of 800-1200nm is reflected by a multilayer film, which performed as a mirror.

Fig. 3 Prototype on the Venlo type greenhouse of 120m^2.

For the conversion of the NIR to electrical energy mono crystalline Silicon Cells suitable for concentrated radiation are used (CPV-cells), which absorb radiation up to about 1150nm. For the determination of the collecting efficiency of the CPVT-module and the optimal position of the lamellae the ray tracing simulation software Raypro was used.

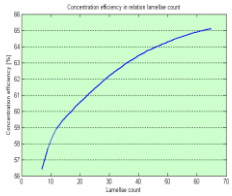

Fig. 4 Average annual concentration efficiency in relation to the lamellae count.

A large number of parameters (material properties, greenhouse dimensions) were taken into account. Theoretically, the number of lamellae for the investigated concept must be high (>100). The concept investigated is a Standard Venlo Type greenhouse with symmetric cover (22° roof slope), a span width of 4.0 m and 60 × 40 mm glazing bars every 1.25 m and a high transparent glass as covering material.

From the raytracing calculations the effect of the number a lamellae is seen in Fig. 4. However very small lamellae will significantly bend due to the gravity forces. With a few, very

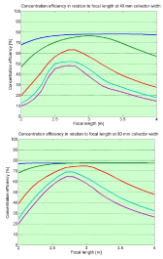

Fig. 5 Concentration efficiency as a function of the lamella width and the generic focal length of the lamellae (—lamel1, —lamel2, —lamel3, —lamel4, —lamel5). Left: Module width 40mm, right: Module width 80mm.

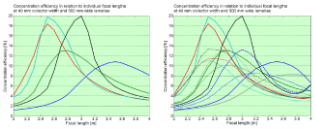

Fig. 6 Left: Concentration efficiency for the 5 lamellae of 800 mm. wide in relation to individual focal length. The blades are numbered from south to north (—lamella 1, —lamella 2, —lamella 3, —lamella 4, —lamella 5). Right: Concentration efficiency for the 8 lamellae of 500 mm. wide in relation to individual focal length. (—lamella 5, —lamella 6……lamella 7, ……lamella 8).

broad (through -shaped) lamellae the concentration efficiency is relative low. The effect of the focal length of the through-shaped lamellae with

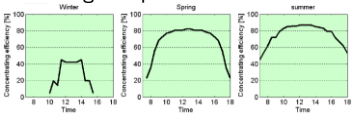

Fig. 7 Concentration efficiency of a system with 8 lamellae of 500 mm for a clear day in winter, spring and summer.

generic focal lengths on the annual yield is presented in Fig. 5. In Fig. 6 the optimal focal distance of each individual lamella was calculated. Despite the increase mold costs in case of individual lamellae focal lengths, this will increase the effectiveness of the concentrator system resulting in an increase energy yield.

Conclusions

A concept of a greenhouse with an integrated concentrated photovoltaic system (CPV) and integrated filter for reflecting NIR based on a concentrating lamellae system is developed. An overview of the results of the CPV lamellae system is given in Table 1. The system with individual optimized lamellae focal lengths and a lamella width of 500mm shows the best annual performance of 29 kWh/m^2 for Dutch climate situations. The energy can be used for delivering on the grid, extra cooling with a pad and fan system and/or a desalination system. The proposed CPV-system has positive side-effects like reducing the heat load (and need for cooling) during summer and blocking of the direct radiation which can be harmful for some crops. A prototype of this greenhouse is constructed in Wageningen (Fig. 2) The Netherlands.

Table 1: Performance of the system for bended lamellae with generic and individual optimized focal distances.

lamellae Variant	Optimal focal distance	Efficiency [%]	Yield [kWh]
5 x 800 mm	generic	52.3	20.3
	individual	71.0	27.5
8 x 500 mm	generic	63.6	24.7
	individual	75.4	29.2

Partner

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