WAGENINGEN UR
For quality of life

PV system integrated in a Solar Greenhouse with NIR selective covering

Piet Sonneveld, Gert Jan Swinkels, Bart van Tuijl, Hans Janssen and Gerard Bot

Background

- The greenhouses in the Netherlands are basically a solar collector of 10,000 ha.
- The incident solar energy is much more than needed for the greenhouse energy consumption.
- 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: 5-15%

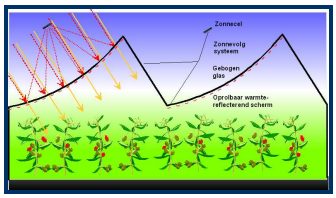

Fig. 1 Principle of the electricity delivering greenhouse. Covering with cylindrical mirror and solar collector (PV cell) in the focal point. (visible light ——► and NIR radiation ——►)

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 mirror.
3. Conversion to electrical energy with PV-cells.
4. Integration of a greenhouse and the solarenergy system

Results & experiments

1. 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 the multilayer film.

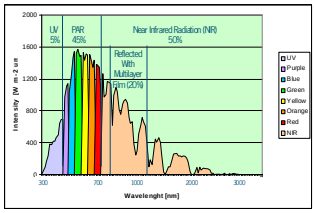

Fig. 2 The AM 1.5 Solar radiation. Radiation between 800 – 1200 nm is reflected by the multilayer film.

2. 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 the multilayer film.

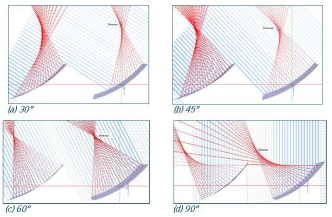

Fig. 3 Positions of the focal points at an angle of incident of the solar radiation of 30, 45, 60 and 90°.

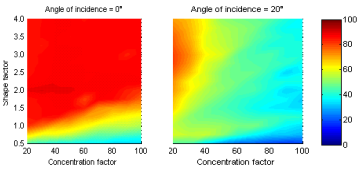

Fig. 4 Yield of a cylindrical trough concentrator as function of the concentration and shape factor for an angle of incidence of 0 °and 20 °. Definition shape factor: radius of the cylinder divided by the chord distance

3. The position of the focal point as a function of the angle of incident is given in Fig. 3. In Fig. 4 the maximal yield is given as a function of the concentration factor and the shape factor. The shape factor is defined as: radius of the cylinder divided by the chord distance.

4. Conversion to electrical energy with

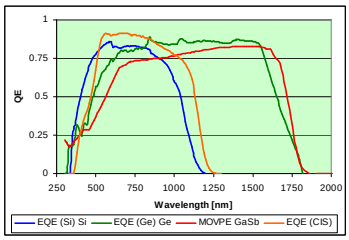

Fig. 5 Quantum efficiencies of four different PV cells: Silicon, Germanium, GaSb and CIGS.

Table 1: Output for wavelength > 750 nm.

system	Band-Gap [eV]	Voc [V]	ISC [A/m²]	Fill-factor	Power Dens. [W/m²]	Eff. [%]
Ge	0.67	0.27	306	0.70	57.8	12.0
GaSb	0.74	0.37	173	0.71	45.8	9.5
CIS	1.05	0.51	172	0.72	63	13.1
Si	1.11	0.65	146	0.80	75.9	15.7
Si+Ge	-	-	-	0.80	99.9	20.7

different types of solar cells is shown in Figure 5. The efficiencies are presented in Table 1.

Fig. 6 Greenhouse at real size of 10x10m

Fig. 7 Side view of the framework with the frame, two linear actuators and the PV cells.

Conclusions

The experimental greenhouse (Fig. 6) at a size of 100m² is built in Wageningen and was ready in June 2008. For the collector Silicon, Germanium, CIS or GaSb cells can be applied. The maximal efficiency of 15,7% energy conversion from the solar radiation with wavelength larger then 750 nm is achieved with Si cells. The application of a combined Si PV and a Ge-cells TPV will result in a elevated efficiency of 20.7%. The PV cells are mounted

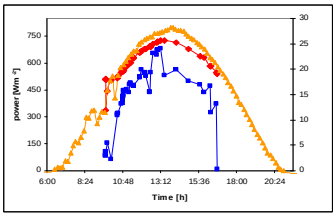

Fig. 8 Output power (scale right P_{nom} ———) and incident radiation at the site (scale left: P_{rad} ———) en Haarweg location Wageningen (P_{rad} ———) measured on Aug. 6th, 2009.

in a framework and controlled in position with two linear actuators. (Fig. 7) The system is integrated in a greenhouse with a covering of curved glass. The concept is feasible with existing materials and components and a peak power of approximately 25 W/m² electrical and thermal peak power of 150 W/m² is expected with an illumination of 900 W/m². The produced energy is determined on 18 kWh/m² and the thermal yield on 107 kWh/m² and can be used for energy supply and/or extra cooling with a pad and fan system and/or a desalination system.

Partner

Bosman Kassenbouw BV, Aalsmeer

Acknowledgement

Financial support by SenterNovem (Ministry of Economic Affairs), Product Board for Horticulture and Ministry of Agriculture, Nature & Food Quality.

bosman

landbouw, natuur en voedselkwaliteit

Productschap Tuinbouw

SenterNovem
Agentschap voor duurzaamheid en innovatie

Kas als Energiebron

Wageningen UR Glastuinbouw
Bornsesteeg 65, 6708 PD Wageningen
Postbus 16, 6700 AA Wageningen
Tel.: +31(0) 317 483 383
Fax: +31 (0)317 423 110
E-mail: piet.sonneveld@wur.nl
Internet: www.glastuinbouw.wur.n