Reducing the Energy Consumption of Greenhouses

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Subjects

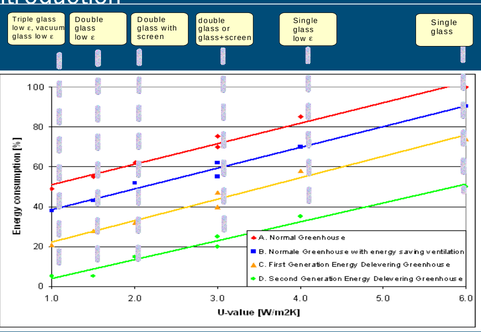
- Introduction
  - Red line: Reducing the U-value
  - Blue line: Energy saving dehumification
  - Orange line: Energy Delivering Greenhouse
  - Green line: Electricity Delivering Greenhouse
- Actual projects
  - Micro-V
  - IDC Energy Delivering Greenhouse
  - Electricity Delivering Greenhouse
  - Fresnellens Greenhouse
- Conclusions

I. Introduction

Methods for energy saving greenhouses

1. Increase of the thermal insulation
2. Reducing the heat losses during ventilation
3. Better utilization of the available solar energy
4. Conversion of the surplus of solar energy to electrical energy

I. Introduction



A.Red line

Red line: Reducing the U-value

- Low emission glass (Hortiplus)
- LNV/PT Project Microstructure coated glass
- EET/LNV/PT Project Solar greenhouse
- EET/LNV/PT Project Nanofoam
- LNV/PT ZigZag Lexan sheet material
- EOS project Micro-V with low emission

B. Blue line

Blue line: energy saving humidity reduction

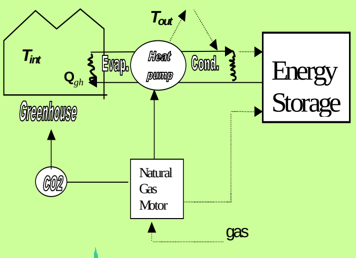
- LNV/PT Energy saving dehumification
- LNV/PT Mechanical dehumification

C. Orange line

Orange line: Energy Delivering Greenhouses

- LNV/PT Project Monitoring the energy delivering greenhouse Bergerden
- LNV/PT Project Measurements on the energy delivering greenhouse at IDC

De Zonnekas Principeschets:



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imag-dlo

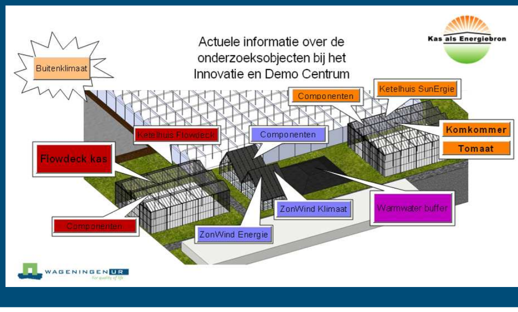
D. Green line

Green line: Energy Delivering Greenhouses (second generation)

- EOS/LNV/PT The Electricity Delivering Greenhouse
- LNV/PT project Fresnel greenhouse

II. Actual projects

1. Measurements on the energy delivering greenhouse at IDC



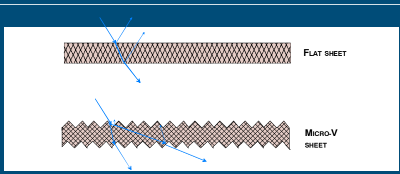
II. Actual projects

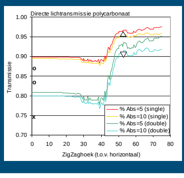
ZonWind Greenhouse at IDC

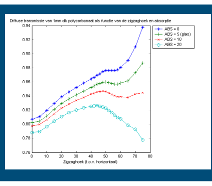
II. Actual projects

2. EOS project
Ultra-energy saving Greenhouse systems with Super transparent Micro-V structured materials

How works Micro-V?





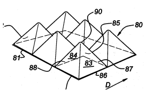


Products/applications

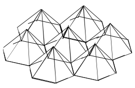
- **Sheet material** (glass & polymer)
  - Solar cells
  - Solar collectors
  - Greenhouses
- **Film** (polymer)
  - Solar cells
  - Solar collectors
  - Screens
  - Film covered greenhouses
  - Lamination on sheet
- **Double sheet** (glass & polymer)
  - Solar collectors
  - Greenhouses

Different structures

V-groeven



Micro piramides met vierkante basis



Micro piramides met hexagonale basis

Rendement PV Cel a-Si dikte 0,5 en 2 micron (direct licht)

System	Extra Absorption %	Extra Efficiency %
Micro-V grooves	20-21	**48-42**
Micro pyramids (rectangular)	23-22	**55-44**
Micro pyramids (hexagonal)	23	**55-46**

Hoogste winst bij zonnecellen:
Micro-piramides met hexagonale basis

II. Actual projects 3. The Electricity Delevering Greenhouse

Objectives

- Better utilization of the available solar energy
- Improving the climate conditions in the greenhouse
- Economically feasible

II. Actual projects 3. The Electricity Delivering Greenhouse

Bottlenecks:
- PV cells and greenhouses use both PAR
- Accession of light is of great importance for horticulture
- PV is expensive
- In summer no demand for heat

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Introduction

Preconditions:

PV cells and horticulture using both PAR
- Transparent PV cells?
- With concentrated radiation 30-100x less light losses
- Horticulture without NIR Radiation?
  - Resulting in the Electricity Delivering Greenhouse
- Pot plants without direct radiation?
  - Resulting in the Fresnel lens Greenhouse

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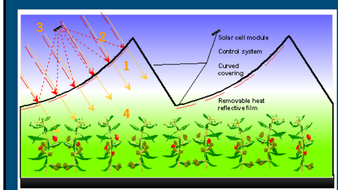
Introduction Electricity Delivering Greenhouse



Principle of operation
1. Separation of the NIR radiation and PAR
2. Focusing of the NIR radiation
3. Conversion to electrical energy
4. Integration in an greenhouse system.

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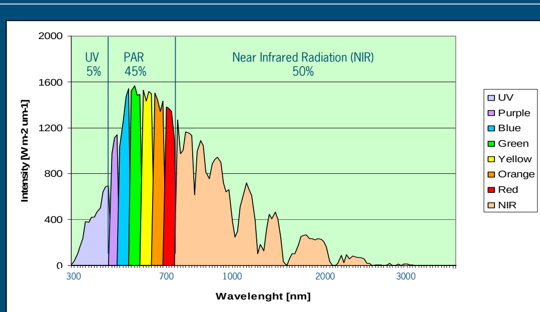
1. Spectral selective film: separation PAR/NIR-radiation.



Spectrum of AM 1.5 solar radiation

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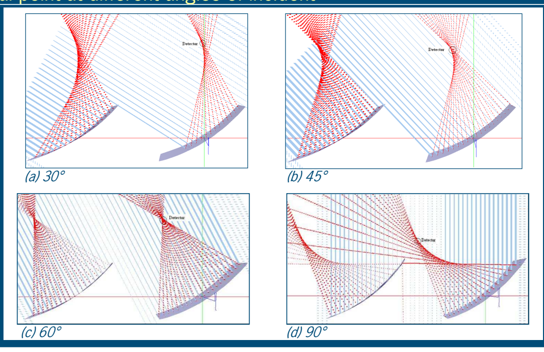
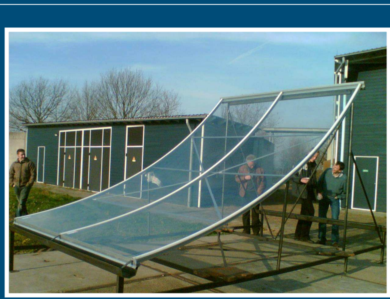
2. Concentration system

Focal point at different angles of incident

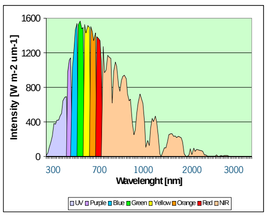


2. Concentration systems

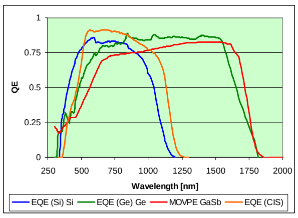


Curved glass greenhouse cover

3. Energy conversion



Solar Spectrum AM 1,5



Quantum efficiency (T)PV cells

Efficiencies PV and TPV systems

3. Energy conversion Efficiencies for radiation with l >750nm

system	Band-Gap [eV]	V_{OC} [V]	I_{SC} [A/m^2]	Fill-factor	Power Dens. [W/m^2]	Eff. [%]
Ge	0.67	0.27	306	0.70	57.8	12.0
GaSb	0.74	0.37	173	0.73	70.0	14.5
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

yearly yield of Si cells 15 KWh/m2y (Dutch climate)

5. Integration in a greenhouse

Drawing | Scale model | Real size

5. Integration in a greenhouse

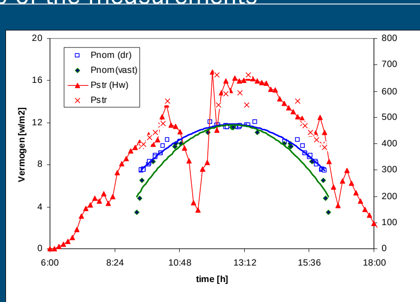
The ELKAS

Side view of the greenhouse construction

5. Integration in a greenhouse

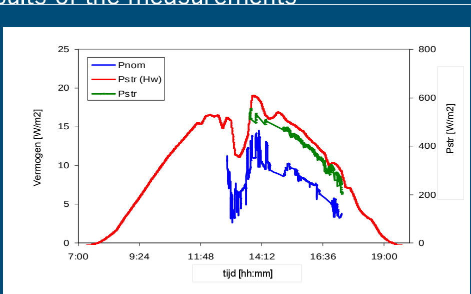
Tilted photo?

Results of the measurements



Measurements 11 september 2008

Results of the measurements



Metingen 26 september 2008

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Results of the measurements

Parameter/meetdatum	26 sept. 2008
P_{str} [W/m²]	600
P_{dir} [W/m²] (69% van P_{str})	414
P_{nir} [W/m²] (15% van P_{dir})	62
P_{refl} [W/m²] (15,6% van P_{str})	62
P_t [W/m²]	124
P_{th} [W/m²]	50
P_{nom} [W/m²]	15
Thermic Efficiency [%]	40
PV Efficiency [%]	12

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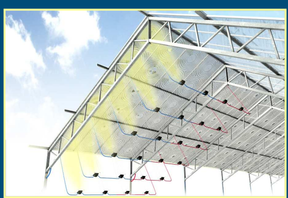
II. Actual projects: 4. Fresnellens greenhouse



Extra objectives:
1. Homogeneous illumination
2. Screening or chalking no longer required
3. Control: Complete pass at low light intensities
4. Heat available for buffer or aquifer
3. Economic achievable
6. Safe system

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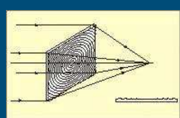
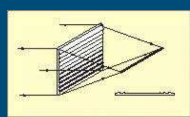
How does a Fresnellens work?





- Thickness of the lens is much lesser compared with normal lenses
- Works like a normal lens: All direct radiation is focusing to a focal point or line

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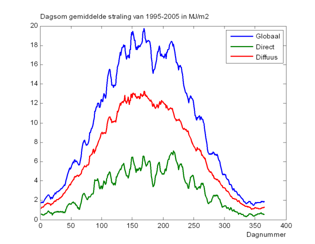
Available Energy



Average radiation of the last ten years

The energy totals are

Global 3560 MJ/m²
Direct 1100 MJ/m²
Diffuse 2460 MJ/m²

Transmission greenhouse 0,80
Transmission direct lens 0,90
Efficiency Si-cell 0,15
Max. yield: 119 MJ/m²
=33 KWh/m²

Efficiency Triple junction 0,30
Max. yield: 238 MJ/m²
=66 KWh/m²

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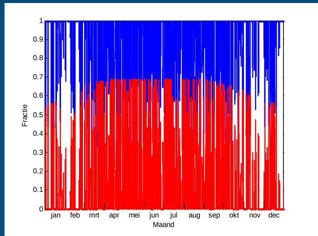
Screening factor



Direct and diffuse light distribution determined from hourly values

- Max. 69% direct radiation
- Maximal transmission greenhouse covering for diffuse light =80%. Part of diffuse is 31%.
- Maximal screenings part is:
  69+ 31x 0,8= 81%.

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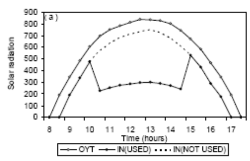
Available Energy



Example of radiation control during one Day (Measured in Greece)

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Integration in a greenhouse

Fresnel lenses placed between double glass

The Fresnel greenhouse

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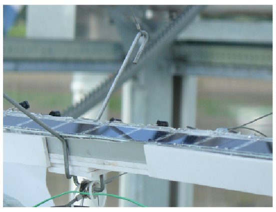
Integration in a greenhouse



PV-module

Tracking system with steel cables

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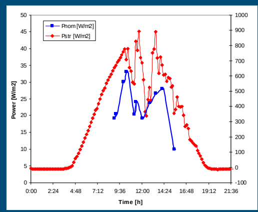
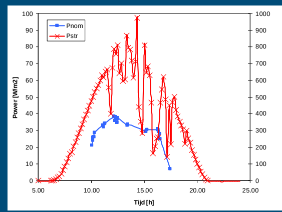
Results





Measurements at Juli 31 and August 15 2008

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Results of the measurements

Parameter/ date	18 sept. 2008
P_{str} [W/m^2]	645
P_{dir} [W/m^2] (69% van P_{str})	445
$P_{dir\ -inkas}$ [W/m^2] (70% van P_{str})	311
P_{them} [W/m^2]	170
P_{nom} [W/m^2]	34
Thermic Efficiency [%]	55
PV Efficiency [%]	11

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Conclusions

Both greenhouses:
- More complete usage of the available solar energy (UV/VIS and NIR)
- During summer a better climate in the greenhouse
- Delivering of heat and electrical energy

Electricity Delivering Greenhouse
- Useable for all types of crops
- Excluding NIR heat radiation into the greenhouse (cooler greenhouse)

Fresnel lens Greenhouse
- Elevated energy yield
- Special useable for pot plants
- No direct light therefore less minder risk on burn damage
- Screening or chalking no longer needed

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