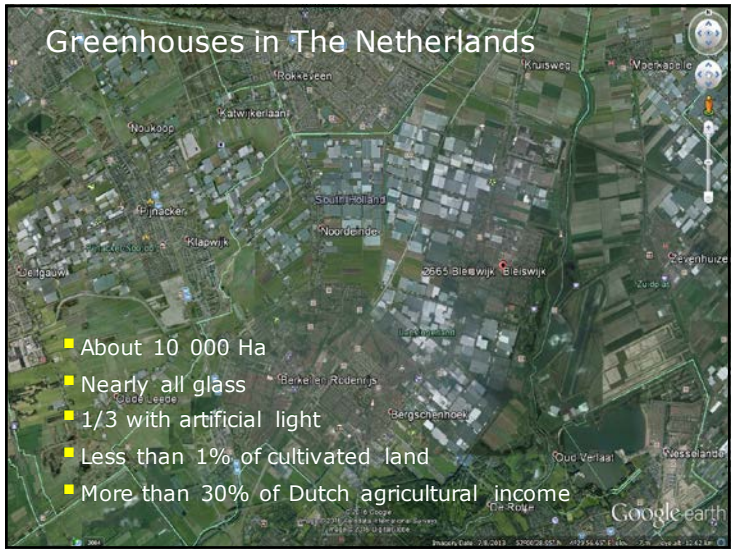
Requirements and technology for smart materials in greenhouses

Workshop 13 April 2016, Bleiswijk

Dr. Silke Hemming, Wageningen UR Greenhouse Horticulture

Greenhouses in The Netherlands



- About 10 000 Ha
- Nearly all glass
- 1/3 with artificial light
- Less than 1% of cultivated land
- More than 30% of Dutch agricultural income

Horticultural crops

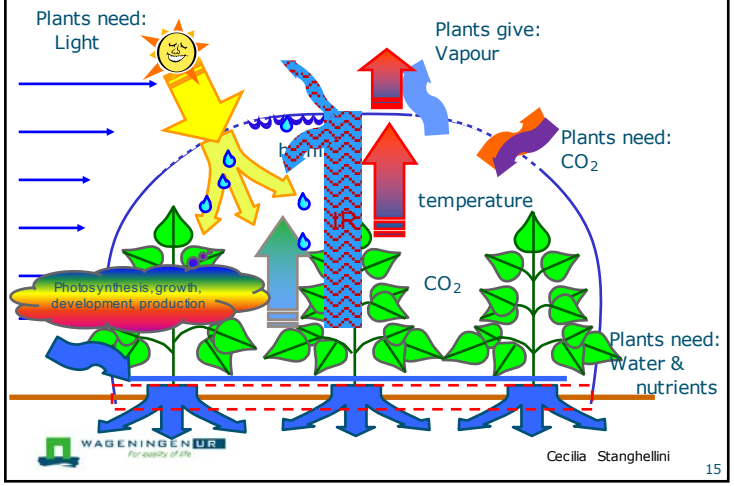
Vegetables [4750 ha]
- 1750 ha tomato
- 1200 ha pepper
- 550 ha cucumber

Cut flowers [1880 ha]
- 390 ha chrysanthemum
- 280 ha rose
- 160 ha gerbera

Potted plants [1300 ha]

Anja Dieleman

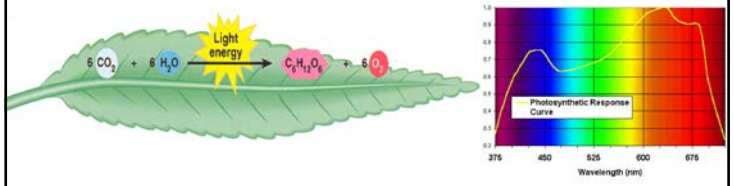
Important function greenhouse covering



Cecilia Stanghellini

PAR light and photosynthesis

- Most important process for plant growth:

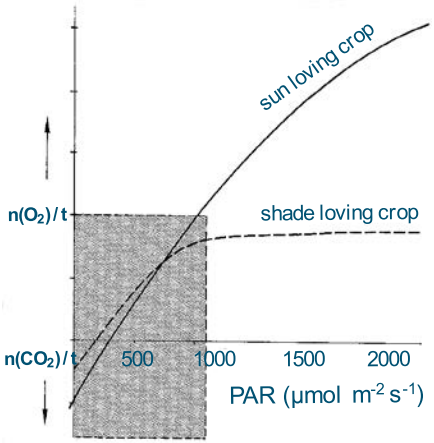


- Light energy is used to convert CO_2 into carbohydrates

Light quantity

Photosynthesis depending on

- crop
- light intensity



Light quantity - limiting factor in NL

yield increase per % light increase

Crop	% Yield increase
Lettuce	0.8
Radish	1
Cucumber	0.7-1
Tomato	0.7-1
Rose	0.8-1
Chrysanthemum	0.6
Pointsettia	0.5-0.7
Ficus benjamina	0.6

Source: Marcelis et al., 2006

Light quantity

More light by…

- Advanced covering material
  - White glass (+1-2%)
  - AR on glass (+5-8%)
  - New plastic films ETFE, PVDF (+3%)
- New screens and coatings
- Lighter greenhouse construction, less installations
- Roof angle, orientation
- Cleaning (up to 10%)

Light quality

Light quality (plant shape, flowering, colour): steering light

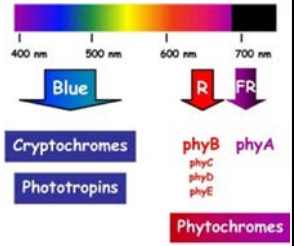
- UV, purple, blue (300 - 500 nm)
- Red (600 – 700 nm)
- Far red (700 – 800 nm)

Anja Dieleman

Light quality – plant receptors

Via photo receptors:

- Phytochromes: R/FR ratio
- Cryptochromes: day length
- Fototropins: movement to light, stomatal opening



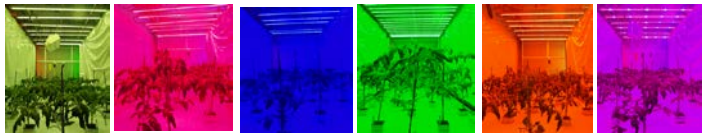
- Influences plant hormonal balances (auxins, gibberellins, cytokinins)
- Thereby effects on elongation, flowering, secondary metabolites, etc.

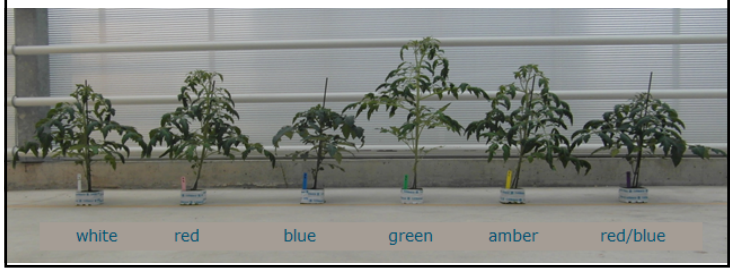
WAGENINGEN UR

Anja Dieleman

Effects of light colours - LED

Anja Dieleman

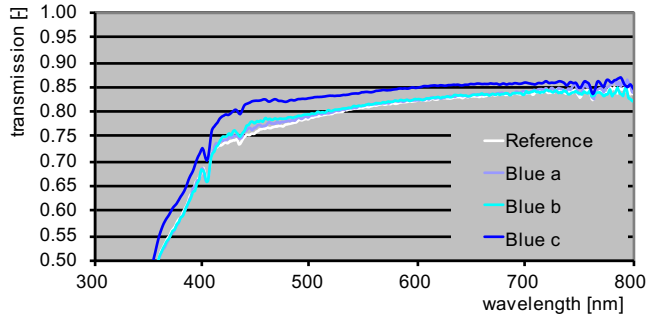




Effects of light colours – natural light

WAGENINGEN UR

New trends: light spectrum & fluorescence

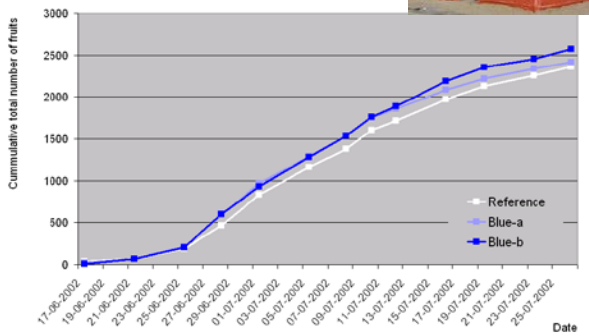


Spectrum changes are often combined with light reductions
→ Interaction morphogentic effects and photosynthesis

Source: Hemming et al. (2006)

Light spectrum: plastic films

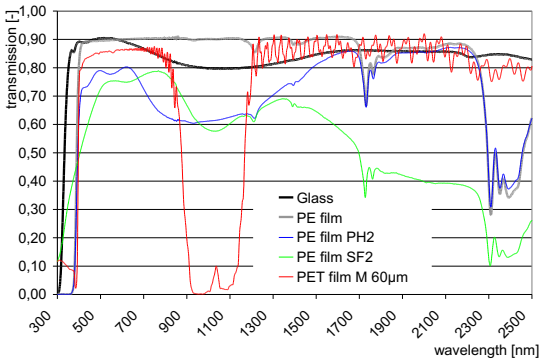
- Number of fruits - strawberry



EU-Spectrafoil

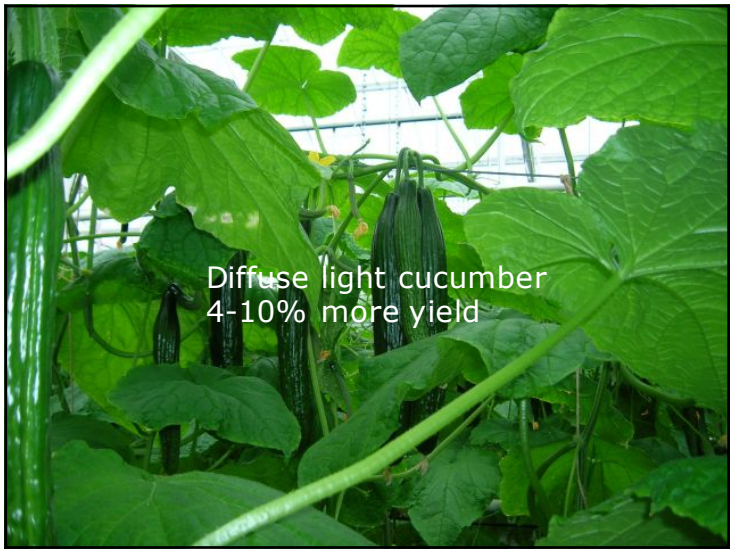
Source: Hemming et al. (2006)

NIR-filtering materials



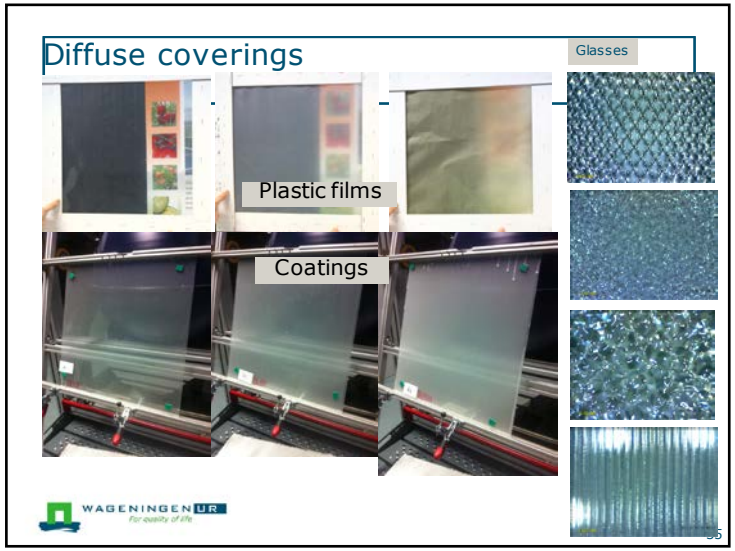
Source: Hemming et al. (2005)

Diffuse light

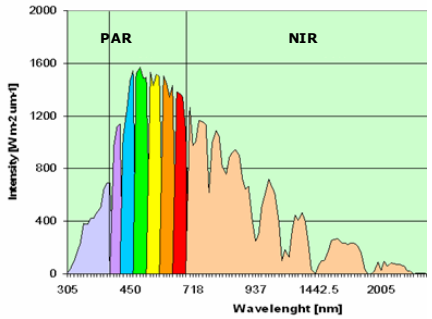

Diffuse light cucumber
4-10% more yield


Diffuse light tomato
8-10% more yield


Diffuse light anthurium and bromelia
25% faster & 25% more fresh weight


Diffuse coverings
Glasses
Plastic films
Coatings
WAGENINGEN UR

Solar radiation



Solar radiation in Bleiswijk, The Netherlands, in 2012:
Total radiation: 3745 MJ m^{-2} y^{-1}
Direct radiation: 1760 MJ m^{-2} y^{-1}
Diffuse radiation: 1995 MJ m^{-2} y^{-1}

Greenhouse production uses sunlight

Make use of natural sunlight

90 mol PAR →
1 kg fresh weight tomato

8-10 mol d^{-1} sunlight
→ pot plant production

High productivity and energy neutral: the squaring of the circle?

- Highly PAR-transparent greenhouse cover
- ...yet good thermal insulation
- Closure of the energy loop (excess/demand) not at greenhouse level → producing electricity
- Which excess energy to use?
  - Not heat (is inefficient)
  - Not PAR (as far as possible, exception potplants)
  - NIR (although it may increase heating requirement)
  - Direct light (in some cases)
  - UV (in most cases)

Cecilia Stanghellini

Heat and electricity production on roof at Wageningen UR Greenhouse Horticulture...

- IDC Energy

ZonWind kas

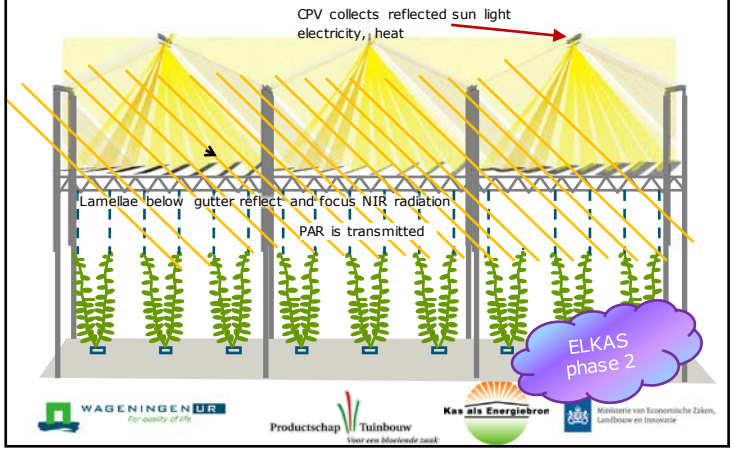
Productschap Tuinbouw
Kas als Energiebron
Ministerie van Economische Zaken, Landbouw en Innovatie

Other examples

- Fotos: Hermans Techniek Nederland bv, Kaatsheuvel
  fotos: van der Valk Systemen, Monster

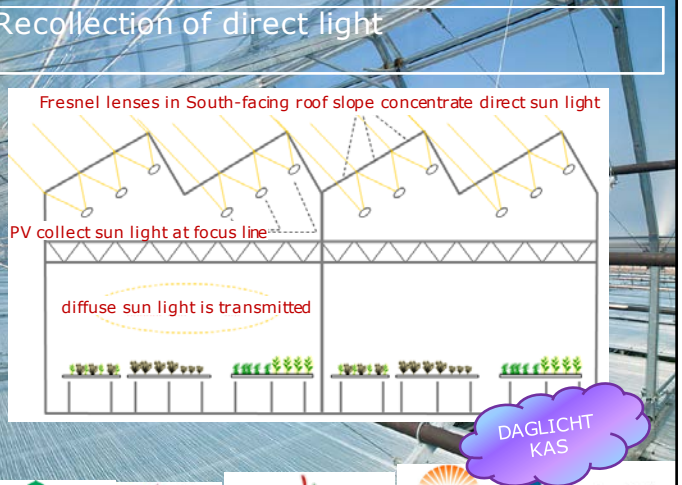
NIR recollection at Wageningen UR Greenhouse Horticulture...

NIR recollection at Wageningen UR Greenhouse Horticulture...



NIR recollection at Wageningen UR Greenhouse Horticulture...

Recollection of direct light



DAGLICHT KAS

TECHNOKAS · Productschap Tuinbouw · Kas als Energiebron

Linear Fresnel lenses and CPV collector

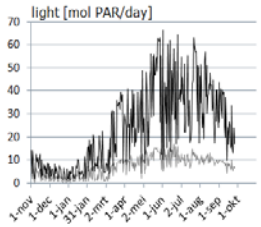
Click for video

DAGLICHT KAS

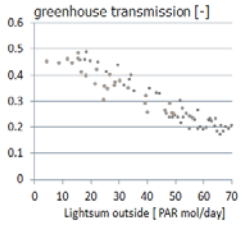
WAGENINGEN UR

De Zwart et al., 2011

Results Fresnel greenhouse - light regulation



- Measured daily PAR light sum outside (black line) and inside (grey line) Fresnel lens greenhouse from November, 1st 2011 until October 1st, 2012.

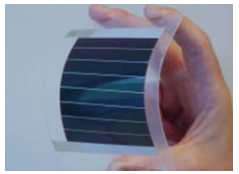


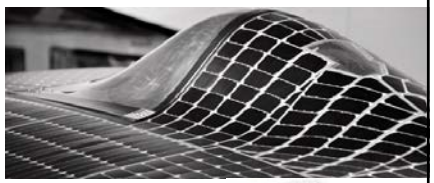
- Measured daily greenhouse transmission in Fresnel lens greenhouse depending on outside PAR light sum, data from November, 1st October 1st,

DAGLICHT KAS

WAGENINGEN UR

Flexible solar cells



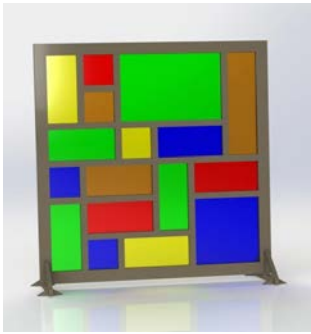


- www.zonnepaneelfolie.nl
- www.zonnepanelen-experts.nl
- www.solarpartner.nl

Transparant solar cells

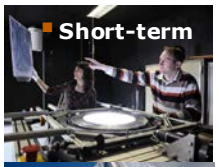
www.zonnepanelen.nl
www.deingenieur.nl

Luminscent solar concentrators

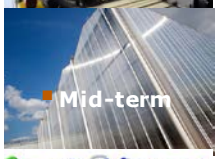


- Tu/e, TUU

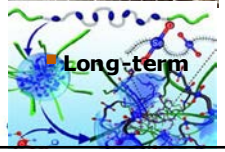
PPS = new ideas



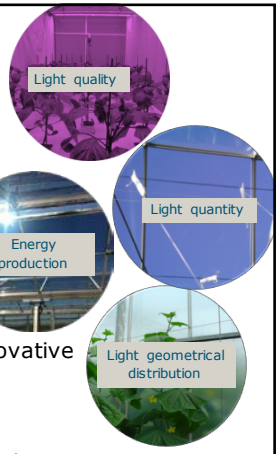
material testing



adaptation to innovative



new material development



Networking

Questions?