

Advanced covering materials – The future?

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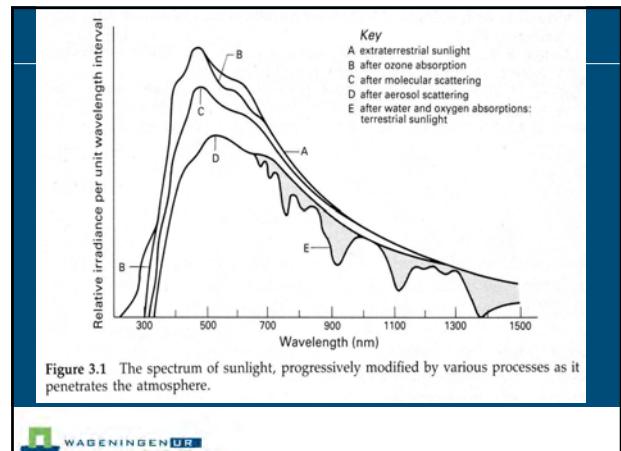
Greenhouse coverings

- Glass
 - Floatglass – Greenhouse glass
 - White glass – Low-iron, Crystal Clear, Optiwhite, Clear glass, Ultrawhite, Diamantglas
 - AR glass – Coating or surface treatment, Sunarc AR glass, Centrosol HiT, GroGlass AR
 - Diffuse glass – surface treatment with different structures, Vetrasol, V&V diffusus, Centrosol Struktur

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General

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General

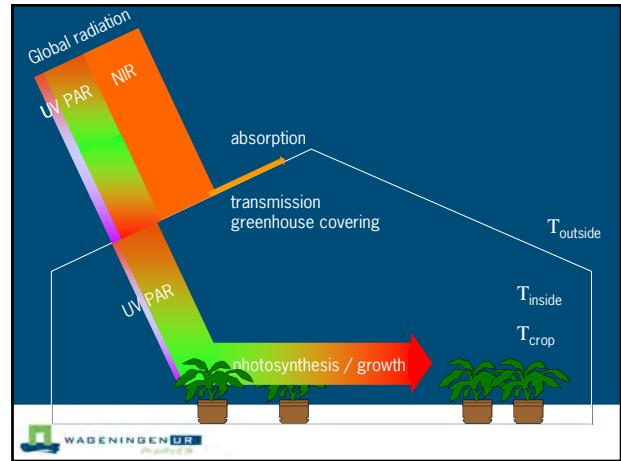
Solar radiation (300-2500nm), energy input greenhouse

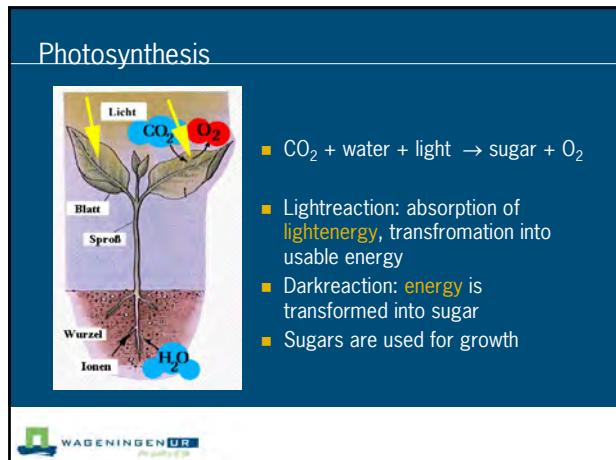
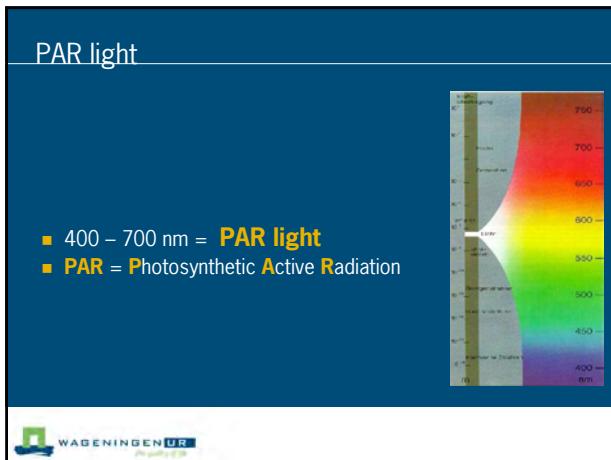
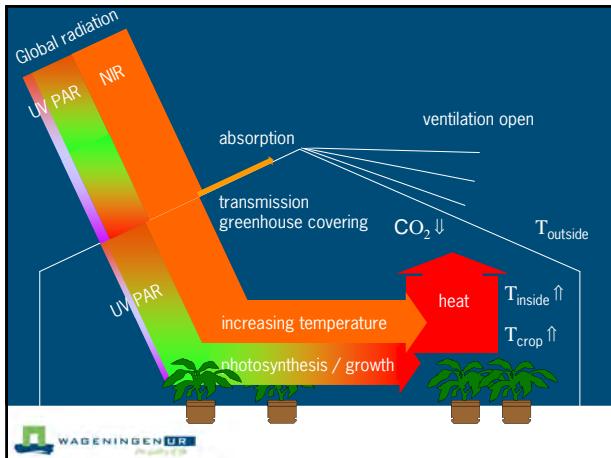
Relevant for horticultural applications

UV	300-400 nm morphogenesis
PAR	400-700 nm photosynthesis, morphogenesis
FR	700-800 nm morphogenesis
NIR	800-2500 nm increasing greenhouse temperature
FIR	2.5-100 µm heat radiation

Heat radiation, energy loss greenhouse

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More light



More light by...

- Advanced covering material
 - White glass (+1-2%)
 - AR glass (+5-7%)
 - ETFE (+3%)
- Lighter construction (max +5%)
- Roof angle (<1%)
- Greenhouse orientation (+1-2% yeararound)
- Cleaning (up to 10%)
- Less installations (+1-3%)



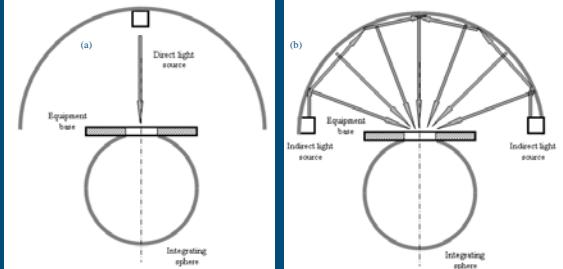
Light transmission

Material	thickness	light transmission	
		perpendicular	hemispherical
Floatglass	4 mm	89-90%	82%
White glass	4 mm	90-91%	83%
AR glass	4 mm	95-97%	89-90%
Diffuse glass	4 mm	90-91%	76-82%
PE / EVA films	200 µm	85-90%	78-82%
ETFE (F-Clean)	100 µm	93%	86%
PC sheet	12 mm	80%	61%
PMMA sheet	16 mm	89%	76%



Light measurement

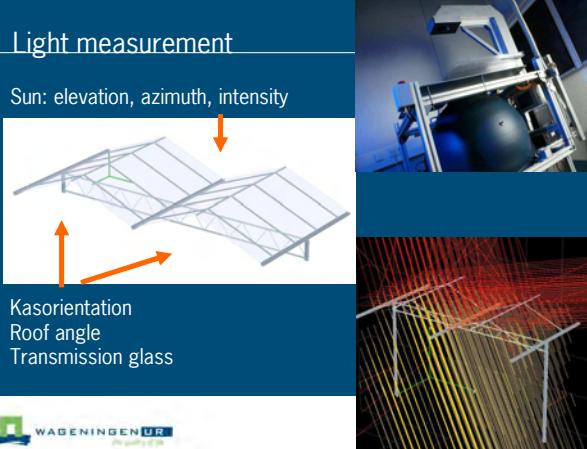
Measure hemispherical light





Light measurement

Sun: elevation, azimuth, intensity



Kasorientation
Roof angle
Transmission glass



AR glass





Light transmission AR treatment

	Standard tönungslicht, Basisglas 1	CentroSolar, Basisglas 3	CentroSolar, Basisglas 3+ AR	CentroSolar, Basisglas 3+ doppel	CentroSolar Basisglas 3+ AR doppel	CentroSolar, Basisglas 4	CentroSolar, Basisglas 4 + AR	CentroSolar, Basisglas 4 doppel	CentroSolar, Basisglas 4 * AR doppel
hemispherical	82.2%	82.4%	89.3%	71.6%	82.2%	84.4%	91.1%	75.1%	86.0%
perpendicular	89.0%	89.3%	94.2%	80.8%	89.7%	91.0%	95.9%	84.0%	92.9%



Condensation behaviour AR glass

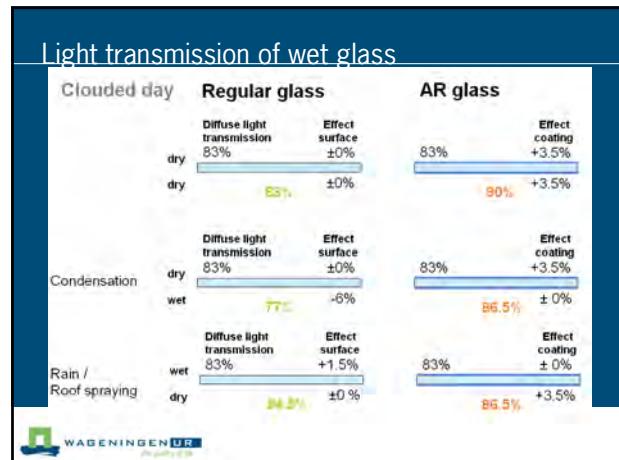
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Light loss by water drops

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Condensation behaviour AR glass

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Diffuse light

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Light diffusion

- Horizontal light distribution
 - Most light intensity at the top of the house due to reflection elements
 - Light intensity decreases with height due to absorption by plants

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Light diffusion

Greenhouse covering materials are able to scatter light rays, transforming direct light into diffuse light

50% Haze 0% Haze

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Light interception cucumber

May 23rd, 2006

Crop height [cm]

Light interception [%]

■ Clear ▲ Diffuse

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Photosynthesis cucumber

June 25th, 2006

Layer	Light Condition	Photosynthesis [$\mu\text{mol m}^{-2} \text{s}^{-1}$]
Upper layer (leaves)	Clear	~22
	Diffuse	~24
Middle layer (stem)	Clear	~8
	Diffuse	~10

Photosynthesis [$\mu\text{mol m}^{-2} \text{s}^{-1}$]

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Crop temperature

temperature diffuse - clear [°C]

time [h]

▲ top ■ bottom

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Yield cucumber

7.8% more fruits
4.3% more fruit weight

Number of fruits (# per m²)

Week nr.

■ Clear ▲ Diffuse

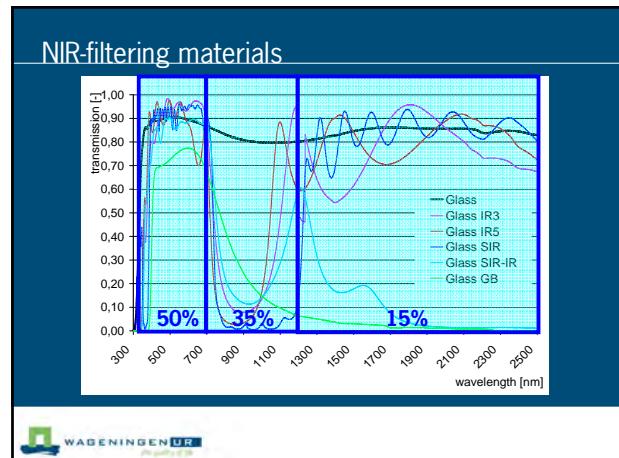
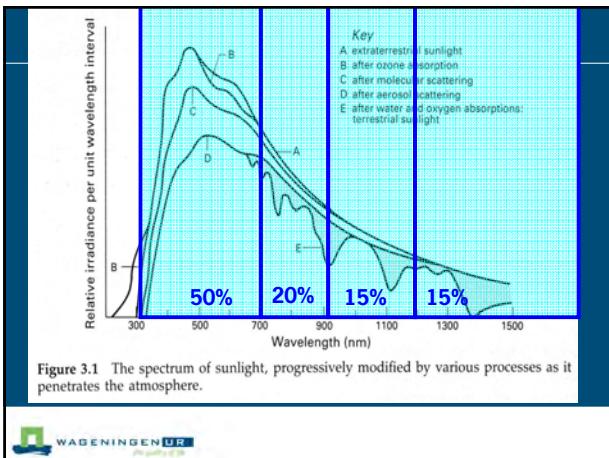
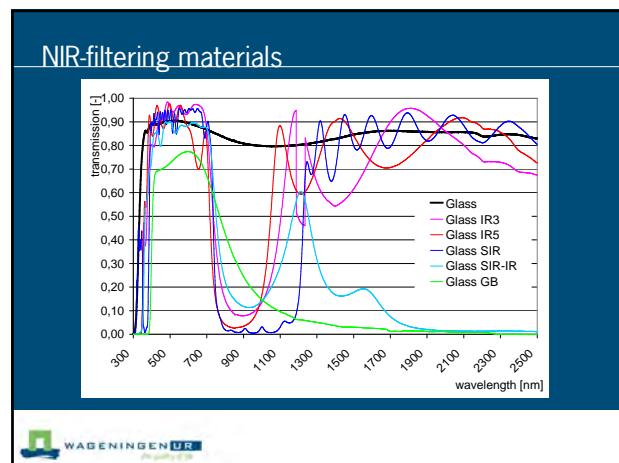
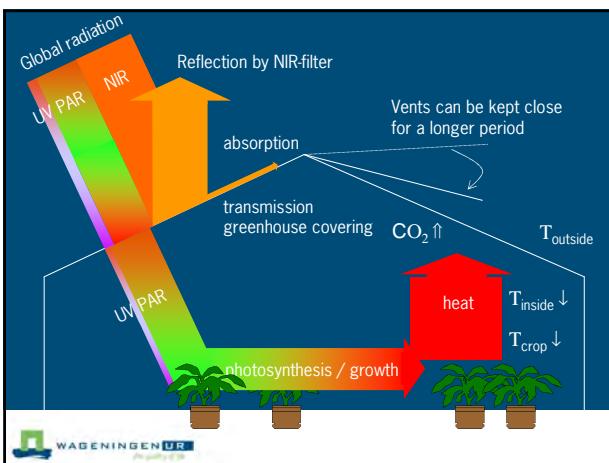
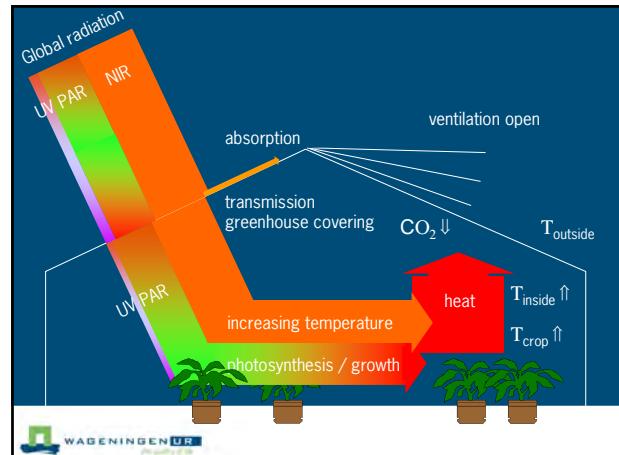
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Materials – haze and light transmission

Material	haze [-]
Difftus glas 3	~0.85
Difftus glas 2	~0.75
Difftus glas 1	~0.30
EVA film diffuse	~0.75
EVA film	~0.30
ETFE film diffuse	~0.75
ETFE film	~0.05
Standaard tuindersglas 4mm	1.00

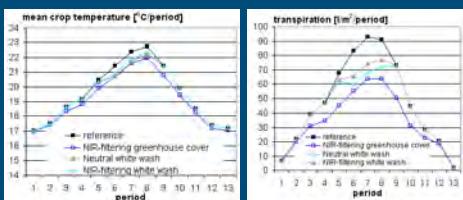
Be careful with light losses at high haze factors

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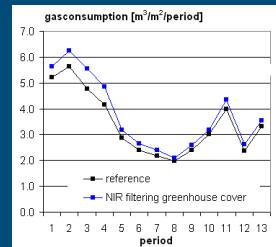
Crop reaction

Air temperature is less affected, crop temperature drops...



Energy consumption

Higher energy consumption with NIR-cover may occur...



NIR-filtering

- Northern Europe:
- In "closed greenhouse" NIR-filtering reduces cooling capacity up to 30%



Conclusions

- Several advanced greenhouse coverings are on the market
- AR glass increases light transmission
- Diffuse glass ≠ diffuse glass
- NIR reflection may be interesting for the future
- -> payback time depending on crop and material costs, mostly < 5 years



Questions?

