Emission-less greenhouses: dream or reality?

Cecilia Stanghellini, Wageningen UR Greenhouse Horticulture
cecilia.stanghellini@wur.nl

EUPHOROS: Efficient Use of inputs in Protected HORticulture

Aim of the project:

In the European protected cultivation to decrease the use of:

- Non-renewable energy
- Water and fertilisers
- Plant protection products
- Substrate waste

Without damage to productivity

Partners: research institutions

- Wageningen UR Greenhouse Horticulture (NL)
- Estación Experimental de la Fundación Cajamar (ES)
- IRTA – Barcelona (ES)
- Università di Pisa (IT)
- University of Warwick (UK)

Partners: business

- HortiMaX (NL)
- Ciba poi assorbita da BasF (CH)
- GroGlass (LV)
- Perlite (IT)
- Terra Humana (HU)
- Cooperativa di produttori Morakert (HU), ora sostituita da Szent István University (HU)

Much good about greenhouses but…

- Even un-heated greenhouse production has a Global Warming Potential equivalent to 250 g_{CO2} per kg tomato
- N-leaching can be some 2 g_{NO3} per kg tomato

Euphoros consortium, 2010

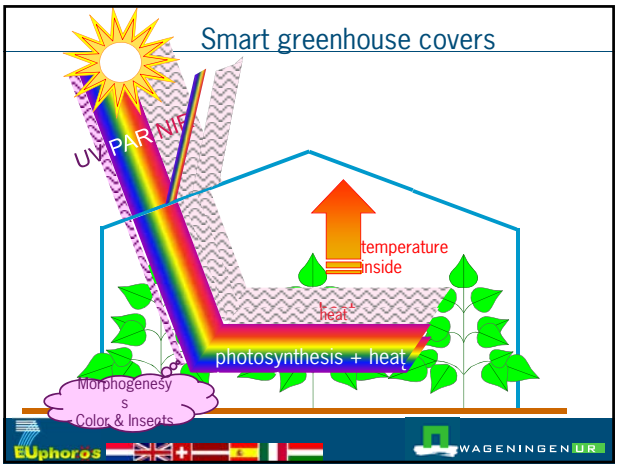
- Tomato production is presently hardly profitable across the EU

➢ Growers will invest in decreasing emissions only insofar as this improves their balance sheet

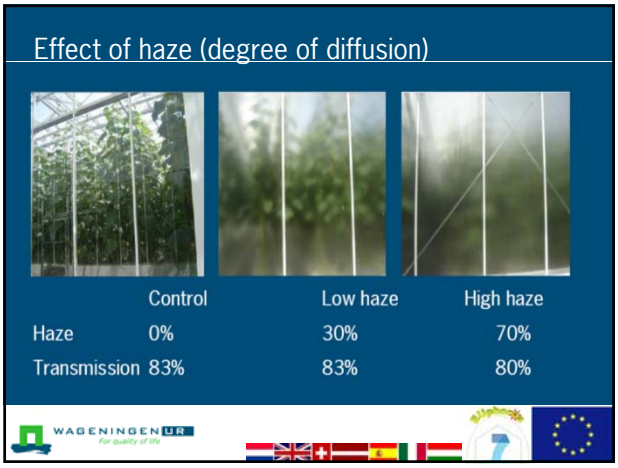
Examples

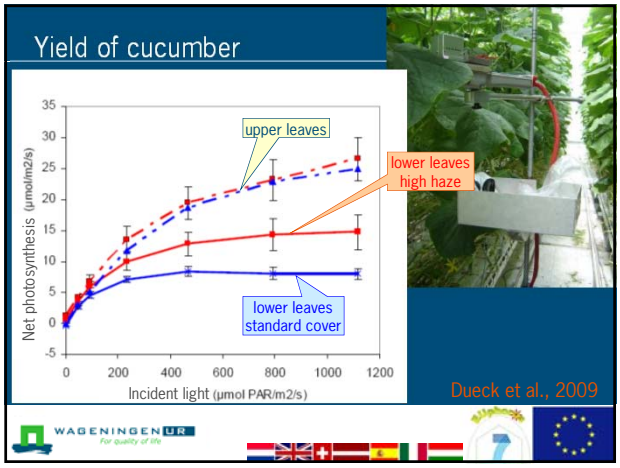
- decreasing resource use = smart design
  - cover materials
  - ventilation capacity
- decreasing waste = process management
  - ventilation
  - thermal storage
  - irrigation management
- evaluation of means for decreasing environmental impact of passive greenhouses

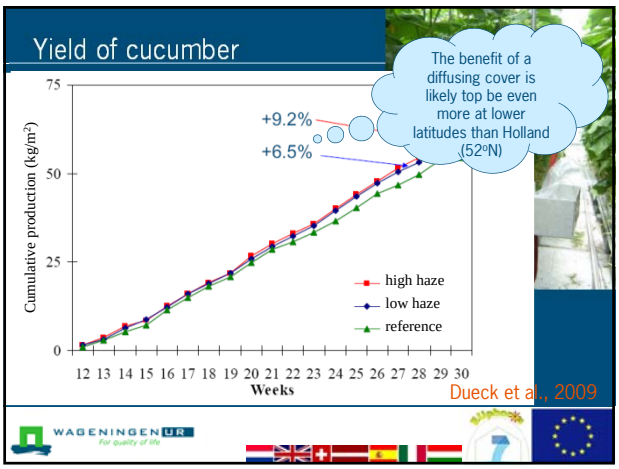
WAGENINGEN UR
For quality of life

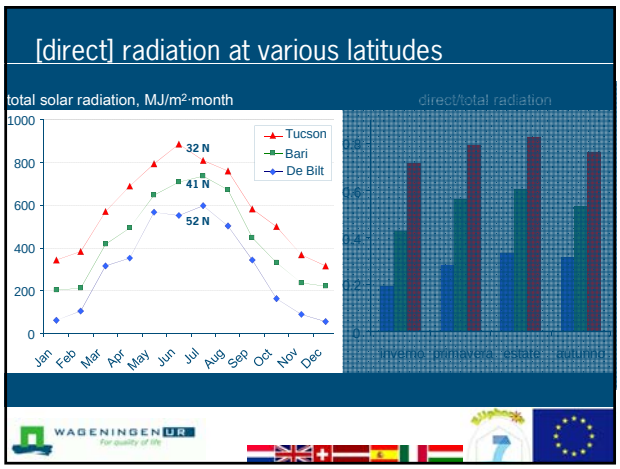

Smart greenhouse covers
UV
PAR
NIR
temperature inside
heat
photosynthesis + heat
Morphogenesys
Color & Insects
EUphoros
WAGENINGEN UR


"wasted" light


Effect of haze (degree of diffusion)
Control
Low haze
High haze
Haze 0% 30% 70%
Transmission 83% 83% 80%
WAGENINGEN UR

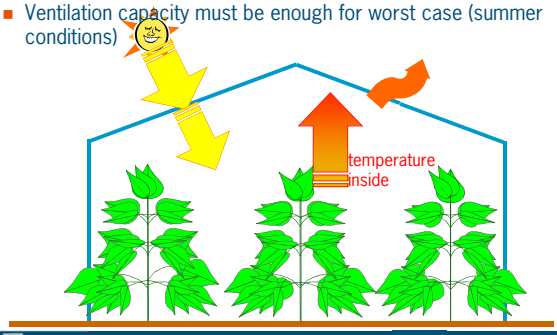

Yield of cucumber
upper leaves
lower leaves high haze
lower leaves standard cover
Net photosynthesis (µmol/m2/s)
Incident light (µmol PAR/m2/s)
Dueck et al., 2009
WAGENINGEN UR


Yield of cucumber
The benefit of a diffusing cover is likely top be even more at lower latitudes than Holland (52°N)
+9.2%
+6.5%
Cumulative production (kg/m²)
Weeks
high haze
low haze
reference
Dueck et al., 2009
WAGENINGEN UR

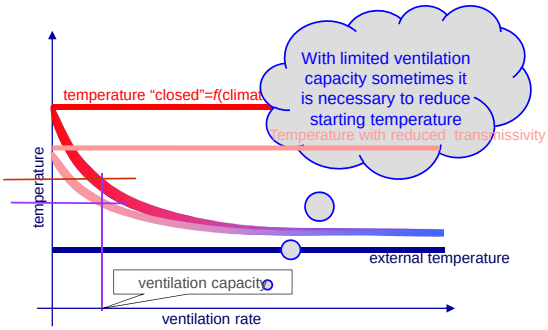

[direct] radiation at various latitudes
total solar radiation, MJ/m²·month
direct/total radiation
Tucson
Bari
De Bilt
32 N
41 N
52 N
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
WAGENINGEN UR

Ventilation design

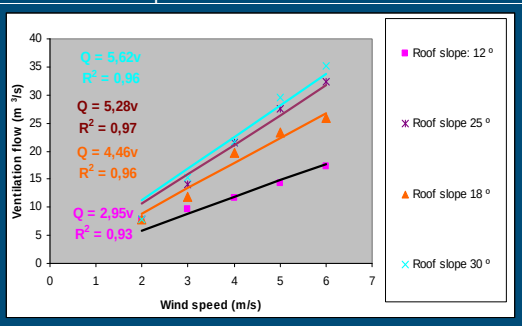
- Ventilation is the cheapest way to get rid of excess sun energy
- Ventilation capacity must be enough for worst case (summer conditions)



effect of ventilation upon temperature

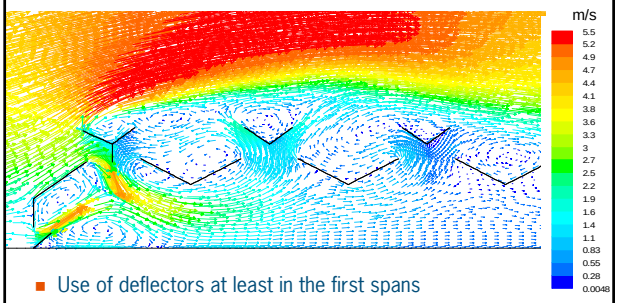


Effect of roof slope on ventilation rate



Baeza, 2007

Suggestions to improve windward ventilation



- Use of deflectors at least in the first spans
- Minimum roof slope 25 º
- Limit the greenhouse width to 50-60 m

Baeza, 2007

Innovative designs being evaluated

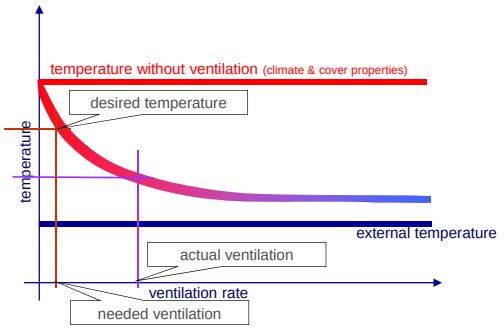
Condensation = light loss (~9%)

- Large slope prevents dripping on the crop
- Anti-drop surface coating would minimize light loss
- So would a [diffusing] glass surface structure Stanghellini et al., 2010

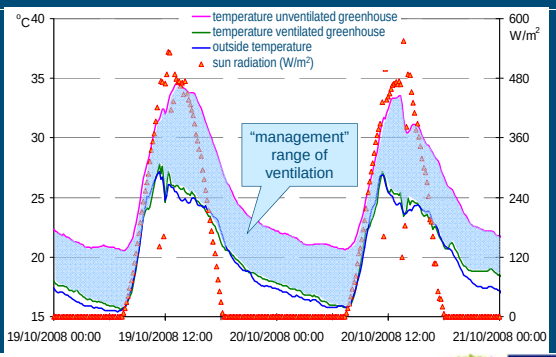
Examples

- decreasing resource use = smart design
  - cover materials
  - ventilation capacity
- decreasing waste = process management
  - ventilation
  - thermal storage
  - irrigation management
- evaluation of means for decreasing environmental impact of passive greenhouses

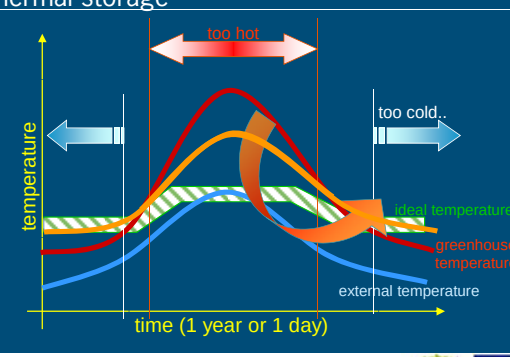
L’effetto della ventilazione sulla temperatura



Ventilation management = regulable openings

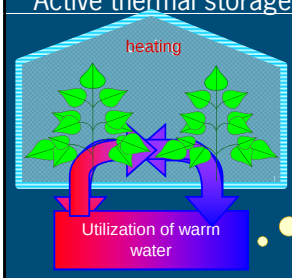


Thermal storage



WAGENINGEN UR
For quality of life

Active thermal storage

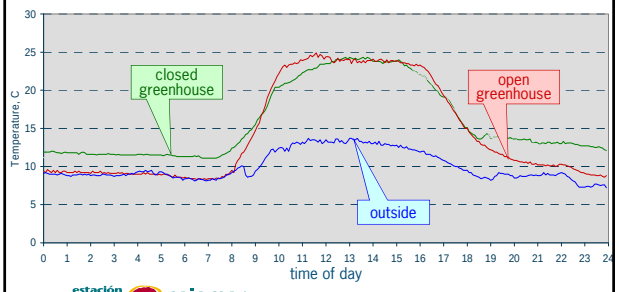


With PERFECT storage a greenhouse has a yearly surplus of energy, EVEN at Dutch latitudes

…and thus much TOO MUCH surplus at lower latitudes ! ➔ semi-closed greenhouses

- Low-temperature storage
  - In [underground] water basins, natural or artificial

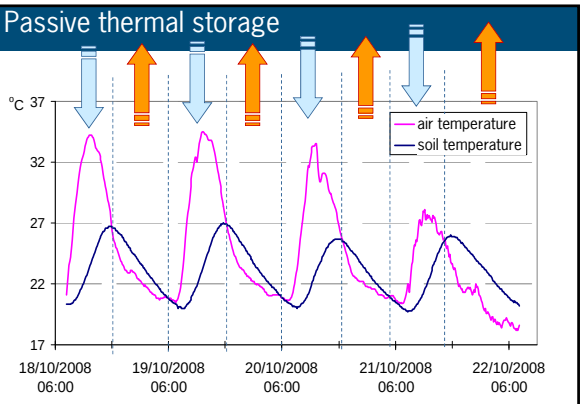
Effect of thermal storage on air temperature



estación experimental cajamar

please attend the lecture by Esteban Baeza

Passive thermal storage



Smart irrigation = less emissions

➔ less need for fertilisers

- Fertilisers costs exceed 10% of production costs in Almeria or even 17% in Hungary
  - (Cajamar, 2009; Euphoros consortium, 2010)
- Yet growers are not exactly eager to adopt smart irrigation
  - (Cuadrado Gomez, 2001; Euphoros consortium, 2010)

Smart irrigation in soil = water on demand

Treatment	Water Use (mm)	Fertilizer (Kg_N/ha)	Mean Crop Weight (g)	Class 1 (%)
A (ref)	186	100	516	98.6
B	70	100	528	98.8
C	70	83	592	97.2
D	70	58	595	98.4

- Irrigation was sensor-driven and soil water content was controlled to prevent leaching

FLOW-AID consortium, 2010 (EU-FP6)

Closed vs open cycle tomato (Italy)

Euphoros consortium, Incrocci, Pisa university: 2010

		Leaching	Supply		Saving
			Open	Closed	%
Water	$m^3\ ha^{-1}$	1067	5334	3982	25
N	$kg\ ha^{-1}$	211.7	1041	621	40
P	$kg\ ha^{-1}$	21	196	149	24
K	$kg\ ha^{-1}$	230.7	1384	1234	11

- Investment could be recovered in 2 years
- Thereafter a saving of some 3500 €/years
- Yet …
  - Fear of "untested" techniques
  - Poor faith in advisory services
  - Concern for root pathologies

➔ The grower won't do it …unless required by regulations

Examples

- decreasing resource use = smart design
  - cover materials
  - ventilation capacity
- decreasing waste = process management
  - ventilation
  - thermal storage
  - irrigation management
- evaluation of means for decreasing environmental impact of passive greenhouses

Cumulative evaluation of environmental impact

- Various production systems/countries
- Most promising actions = decreased environmental impact coupled to financial gain
- Implementation in local conditions to evaluate production
- We have determined the environmental impact of the new technologies
- Through Life Cycle Analysis we calculated the decrease of environmental footprint per unit product

Diminuzione dell'impatto ambientale

Tomato production in a multitunnel in Almeria

	Abiotic depletion	Acidificat	Eutrophicat	Global warming	Photoch. oxidation	Cumulative energy
Reducing fertilisers by 30%	3.6	6.0	15.3	9.7	2.7	3.0
Closed loop irrigation	5.2	9.9	48.2	12.3	5.1	4.9
New greenhouse with improved ventilation	42.6	38.8	36.0	39.3	41.8	42.7

M.Torrellas, A. Antón, E. Baeza, J.C. López, J. Pérez Parra, M. Ruijs, N. García, J.I. Montero, 2011

Conclusion

- There is a strong potential for emission reductions by improving the use of natural resources: particularly sunlight and sun energy
- This is facilitated by technology: innovative structures; process control means
- Other [recycling] technologies are leading towards the zero emissions greenhouse (not discussed here)
- Sustainability is based on three linked issues: environment, economics and social concerns
  - Nothing is achieved until new methods are adopted by growers

Thanks to:

- Jos Balendonck, Wageningen, NL
- Silke Hemming, Wageningen, NL
- Esteban Baeza, EEFC, ES
- Juan Ignacio Montero, IRTA, ES
- Luca Incrocci, Università of Pisa, IT

Thank you!
For your attention
Questions?