Resource use in greenhouses: towards zero emissions

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Decreasing resource input:

- reducing need for resources = smart design
- reducing waste = process management
- increasing productivity = crop management

Content

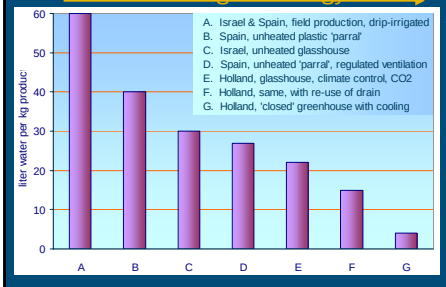
- introduction: the good and the bad news
- reducing need of resources = smart design
  - Greenhouse cover
  - Ventilation capacity
- reducing waste = process management
  - Ventilation
  - Energy storage
  - Irrigation management
- conclusion

The good news

- Thanks to protected cultivation we are eating high-quality and healthy vegetables and enjoying beautiful ornamentals year-round, all at an affordable price
- Protected cultivation is contributing to the economic development of formerly marginal agricultural land around the shores of the Mediterranean and farther
- Protected cultivation has an higher efficiency of use of **most** resources than field crops

Product Water Use of tomato (liters/kg_{tomato})

increasing technology



Van Kooten, Heuvelink & Stanghellini, 2008

Soil use efficiency, for instance Dutch greenhouses:

- occupy < 1% of agricultural area
- generate ~ 40% of national agri-cultural income

Dutch Central Statistical Office, 2008

…and now the bad news

- Even un-heated greenhouse production has a Global Warming Potential equivalent to 220 g_{CO_2} per kg tomato
- N-leaching can be some 2 g_{NO_3} 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

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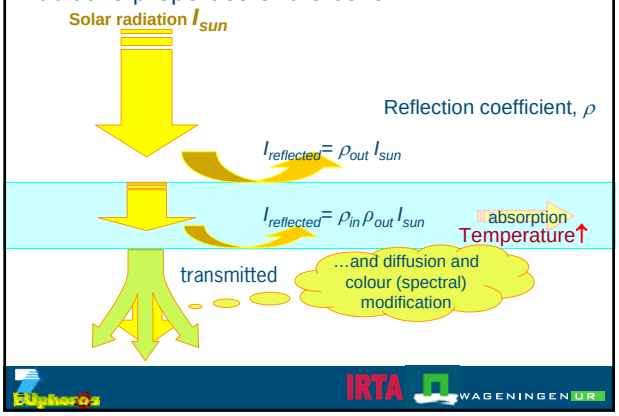
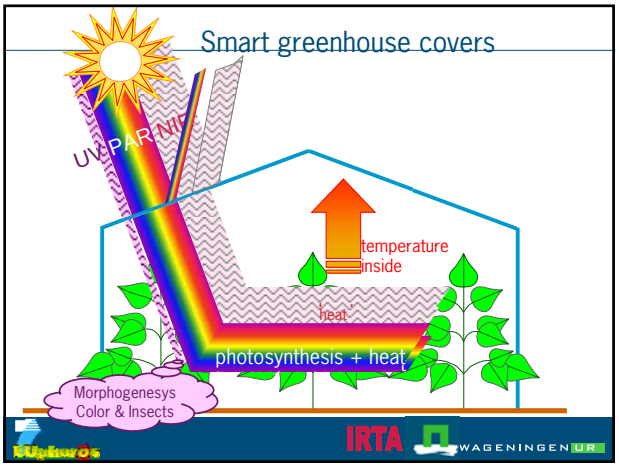
Radiative properties of the cover



Smart greenhouse covers



A word of caution about NIR-selective covers:

- Evolution has already endowed leaves with a high (~50%) NIR-reflectance
  - → Don't expect wonders from NIR-filtering covers
- NIR-absorption will warm up the cover → a fraction of the withheld energy will end up in the greenhouse at longer wavelengths
- NIR-reflection will lead to multiple reflection between crop and cover → a fraction of crop reflection will not escape the greenhouse
  - → Difference in efficacy between absorption and partial reflection may be small
- The contribution of NIR to heating the greenhouse may be welcome often enough
  - → A permanent NIR filter may backfire

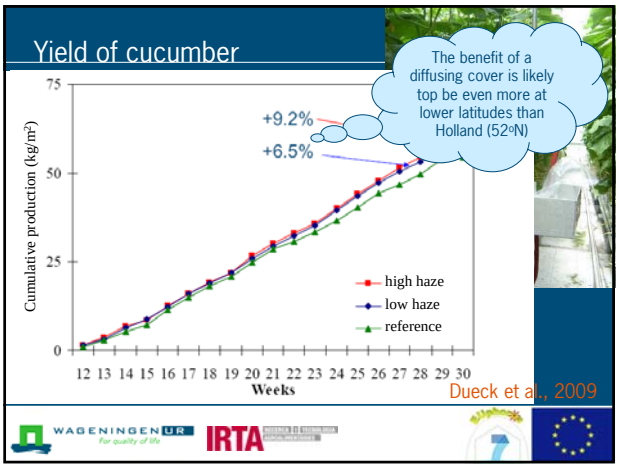
Problems solved by light diffusion

- Vertical light distribution
  - Most light intercepted by upper leaves
  - Lower leaves contribute less to photosynthesis
- Horizontal light distribution
  - Cast shadow from greenhouse construction elements
  - No uniform growth and development in greenhouse

Effect of haze (degree of diffusion)

	Control	Low haze	High haze
Haze	0%	30%	70%
Transmission	83%	83%	80%

Yield of cucumber



Dueck et al., 2009

Light = production (and not only in Holland)

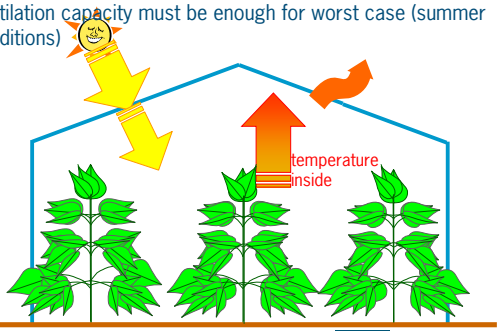
More light by…

- Advanced covering material
  - White glass (+1-2%)
  - AntiReflection glass (+5-7%)
  - ETFE (+3%)
- Lighter construction (max +5%)
- Roof angle & orientation
  - Benefit may depend on latitude
- Cleaning (up to 10%)
- Less installations (+1-3%)

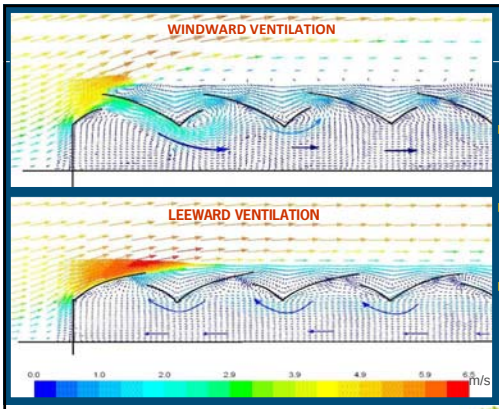
More efficient use of light by diffusion

Ventilation design

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

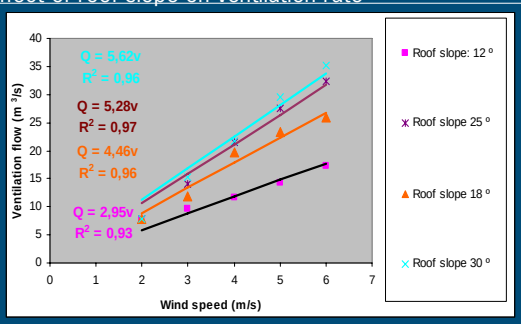


Windward flap:



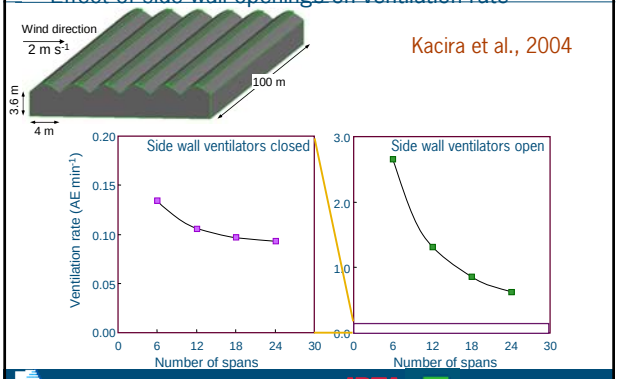
- More air change (about 2x)
- Less climate uniformity
- Care needed to prevent flap damage

Effect of roof slope on ventilation rate



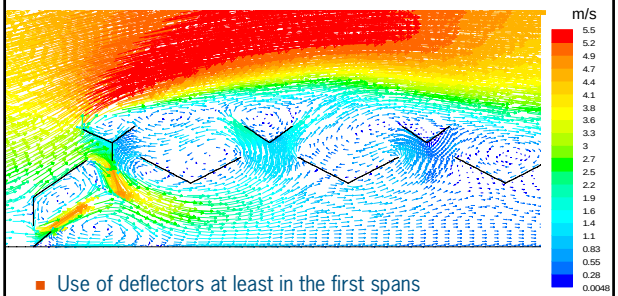
Baeza, 2007

Effect of side wall openings on ventilation rate



Kacira et al., 2004

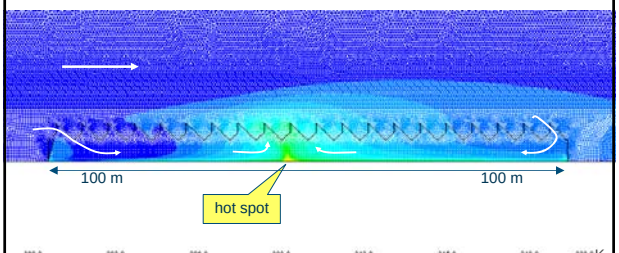
Suggestions to improve windward ventilation



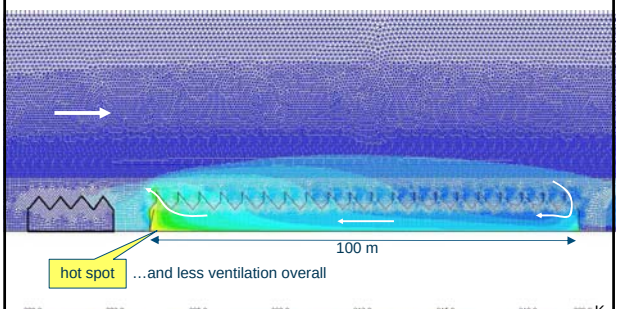
- Use of deflectors at least in the first spans
- Minimum roof slope 25 º
- Limit the greenhouse width to 50-60 m

Baeza, 2007

Large greenhouse: windward ventilation

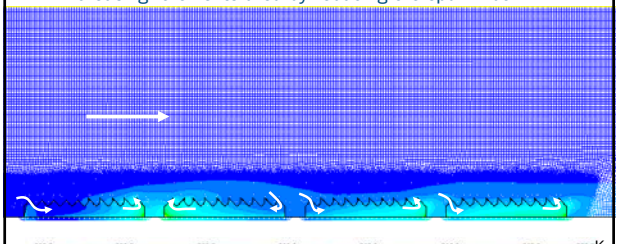


Large greenhouse: effect of neighbours



Solutions under investigation

- limiting the greenhouse width
- keeping an alley between groups
- increasing the vents area by reducing the span width…



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

Wish-list of Almeria's producers

% of producers planning short/mid term to…	2000	2006
Improve the structure of the greenhouse	53.8	26.3
Install ventilation flaps/rolls	35.8	15.3
% who have it already	61.2	84.9

Céspedes López et al., 2009

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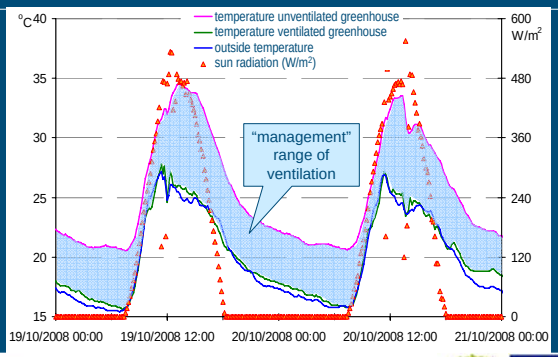
Ventilation management = regulable openings

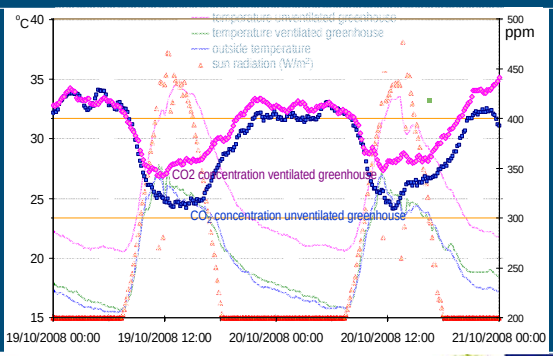


Wish-list of Almeria's producers (now the bad news)

% of producers planning short/mid term to…	2000	2006
Improve the structure of the greenhouse	53.8	26.3
Install ventilation flaps/rolls	35.8	15.3
% who have it already	61.2	84.9
Install automatic ventilation	15.8	3.1
% who have it already		1.2

Céspedes López et al., 2009

Reduced ventilation = need for CO_2 injection

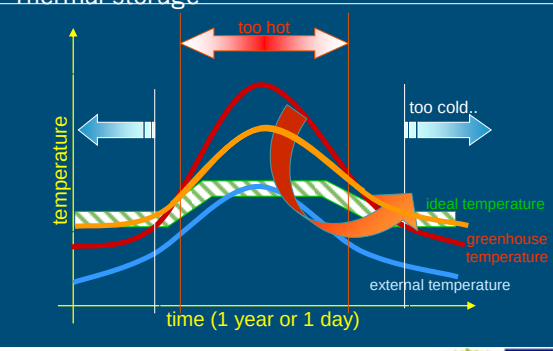


Reduced ventilation (=more-/semi-closed greenhouse)

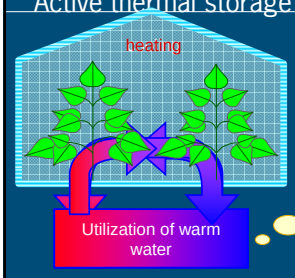
Pro:
- Better management of:
  - Temperature
  - Carbon dioxide
  - Humidity
- Natural thermal storage
- Less pest pressure
  - less need for chemicals
  - less emission if applied

Contra:
- Need for:
  - Automated ventilation
  - Carbon dioxide injection
- Higher humidity
  - The (un)ability to control humidity often limits the scope for reducing ventilation

Thermal storage



Active thermal storage

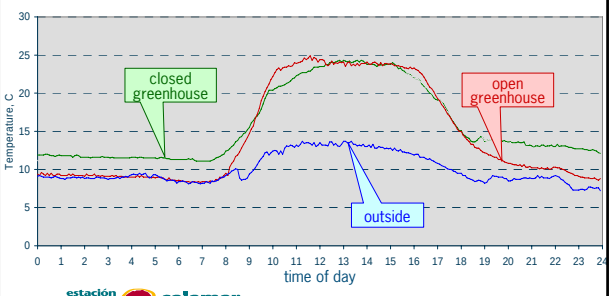


With PERFECT storage a greenhouse has a yearly surplus of energy, EVEN at Dutch latitudes

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

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

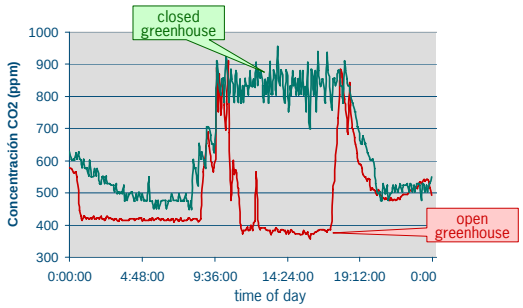
Effect of thermal storage on air temperature



estación experimental cajamar

please attend the lecture by Esteban Baeza

Closed greenhouse and CO_2 concentration



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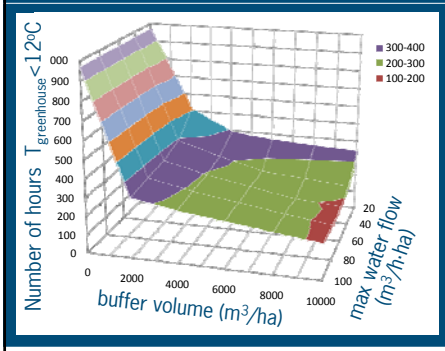
Air temperature vs properties of storage



- After a large initial effect, little marginal benefits
- To have an effect storage volume must be in excess of 200 mm

Kalaitzoglu, van 't Ooster & Stanghellini, 2010

Active thermal storage

No way of reducing ventilation without it

However:

- Low-temperature storage requires a [very] large volume
- …and a very efficient heat transfer
- High-temperature storage requires concentration of energy → low efficiency
- Phase change materials have still to prove their worth
- Please attend the lectures & posters on this topic

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: 2010, please visit the lecture/posters

		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

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; and smart sensors (not discussed in this presentation)
- 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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Questions?
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