New greenhouse concept with high insulating double glass with modern coatings and new climate control strategies

– modelling and first results from a cucumber experiment

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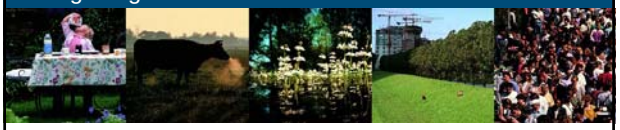

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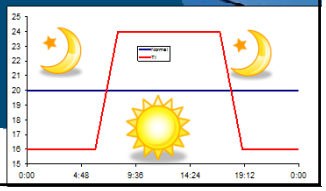
Goals of Dutch horticultural sector

- Targets Greenhouse sector in the Netherlands for 2020:
- -48% CO_2 emission compared to 1990 (-3.3 Mt)
- 2% higher energy efficiency every year
- Greenhouse sector uses 20% sustainable energy
- Economic feasible greenhouse concepts

Problem

- 75-90% of the energy is used for temperature control/heating purposes
- → greenhouse insulation (screen, double covering)
- → temperature integration

e.g. Bot 2001; Hemming et al. 2009; Zhang et al. 1996; Bakker et al., 2008; de Gelder et al, 2010...



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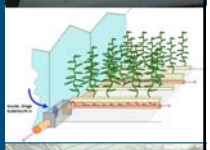
Problem

- 10-25% of the energy is used for dehumidification purposes
- → dehumidification especially important with double covering
- → dehumidification with outside air
- → increase humidity setpoint

e.g. Bakker, 2008; de Gelder et al., 2010; Li & Stanghellini, 2004; Campen, 2009...



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Objective

- Reduce energy consumption of a cucumber crop by at least 60% compared to horticultural practice while maintaining the same crop production levels
  - by new greenhouse concept with high insulating double glass with modern coatings
  - by new climate control / growing strategies

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Material and methods

1. Model calculations with KASPRO (de Zwart, 1996) based on earlier research of Hemming, 2009 (insulating covering materials) and de Gelder, 2010 (new growing strategies)
2. Realisation demonstration greenhouse 500 m^2
3. Validation of model calculations with measurements

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Materials and metho… calculations

Dutch growers

De Gelder, 2010

Hemming, 2009

…ouse concepts and …strategies … with KASPRO

	Reference (traditional greenhouse, climate control like horticultural practice)	New growing strategy (traditional greenhouse, new climate control strategy)	N… (g… new … strategy)
Insulation: Covering	Single glass t_p=91%, t_h=83%	Single glass t_p=91%, t_h=83%	Double glass t_p=88%, t_h ·79%
Screen	AC plastic film XLS 10	AC plastic film XLS 10 XLS 18 Firebreak	XLS 10

*OCAP: dosing capacity 180 kg ha^{-2}h^{-1}; **Fogging: dosing capacity 200 g m^{-2}h^{-1} at vpd=6

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Validation practical data Dutch growers

Validation experimental data De Gelder, 2010

Prediction

…culations …epts and climate … PO fo… …egies

	Reference (traditional greenhouse, climate control like horticultural practice)	New growing strategy (traditional greenhouse, new climate control strategy)	New greenhouse concept (double glass, new climate control strategy)
Gas [m^{3}m^{-2}year^{-1}]	40	25	12
Electricity [kWh m^{-2}year^{-1}]	7	13	18
Cucumber yield [kg m^{-2}year^{-1}]	75	75	75
Energy efficiency [m^3 gas equiv. kg^{-1} produce]	0.56	0.39	0.23

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Materials and methods – demo greenhouse

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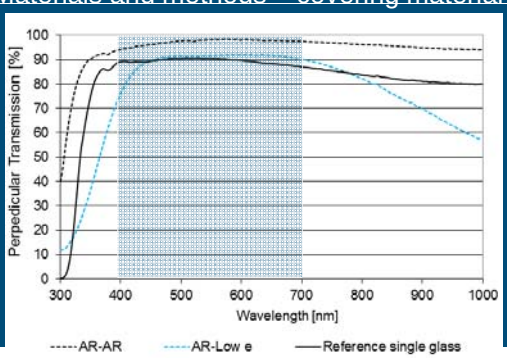
maurice BOAL Climeco solar glass Scheuten

Materials and methods – covering material



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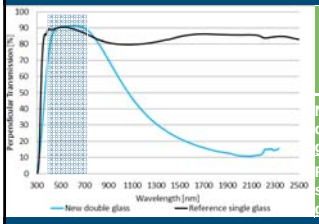
Materials and methods – covering material

- 2x tempered single glasses of 3 mm, split of 10 mm, argon gas
- Single glass AR-AR & single glass AR-low e = new double glass



	PAR Trans-mission τ_p [%]	PAR Trans-mission τ_h [%]	U-value [Wm^{-2}K^{-1}]
New double glass	88.9	79.6	1.2
Reference single glass	89.5	82.3	6.7

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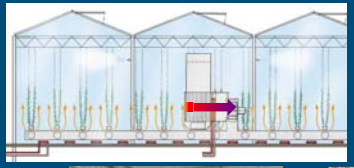
Materials and methods – demo greenhouse

Ventilator & Heat exchanger



Blow in dry outside air
Perforated tubes

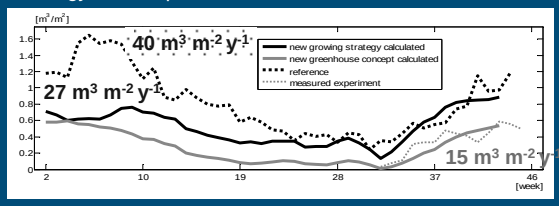
WAGE…

Materials and methods - crop

- Cucumber crop 'Ranomi'
- August, 5th 2010 until November, 16th 2010
- High-wire growing system
- Crop density of 2.2 plants m^{-2}

Results – energy consumption

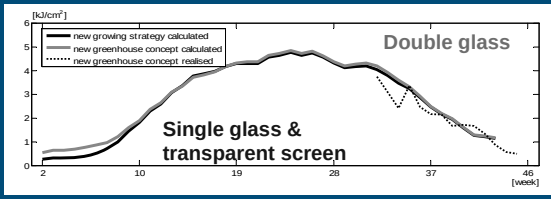
- Calculated (year-round) and realised (week 32 until 45) energy consumption



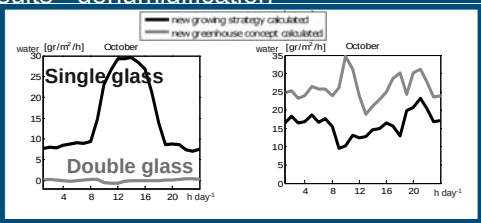
- Calculated: 5.00 m^3 m^{-2}
- Measured: 4.95 m^3 m^{-2}

Results – light level

- Calculated (year-round) and realised (week 32 until 45) light level



Results - dehumidification



- Dehumidification by **condensation** at the inner surface of the greenhouse covering calculated (typical day)
- Dehumidification by the **mechanical system** calculated (typical day)

Results - greenhouse climate

Week number	32	33	34	35	36	37	38	39	40	41	42	43	44	45
rh day [%]	73	78	78	77	79	78	80	79	79	74	72	77	76	78
rh night [%]	86	87	86	84	84	83	85	83	84	78	76	78	80	81
vpd day [g m^{-3}]	6.6	5.3	4.8	5.6	4.8	4.8	4.7	4.6	4.9	5.6	5.6	4.7	4.7	4.3
vpd night [g m^{-3}]	2.7	2.4	2.4	2.7	2.7	2.9	2.6	2.9	2.7	3.5	3.9	3.5	3.1	3.3

- Humidity setpoint night >1-2 vpd / day >3-3.5 vpd was realised
- Dehumidification system worked well, capacity okay

Results – crop

- Realised crop yield during the first cucumber crop in the new greenhouse concept (week 32 until 45)

Week number	32	33	34	35	36	37	38	39	40	41	42	43	44	45
yield cucumbers [fruits m^{-2}]			3.6	4.4	7.1	6.4	5.1	5.6	4.2	2.9	4.3	2.8	4.2	2.7
yield cucumbers [kg m^{-2}]			1.6	1.8	2.8	2.6	1.9	2.3	1.6	1.1	1.7	1.2	1.5	0.9
average fruit weight [g $fruit^{-1}$]			449	406	398	402	383	413	392	377	396	439	364	342

- Total crop yield: 21 kg m^{-2} (53 fruits m^{-2}) → conform practice

Conclusions

- Energy consumption very low (ca. 60% decrease), as predicted by models
  - High insulating covering & energy screen (night)
  - Mechanical dehumidification and heat regain
  - Temperature integration
  - No limitation of CO_2 in our experiments
- Crop yield conform practice, good quality
- Year-round data has to be collected: tomato crop started in December 2010

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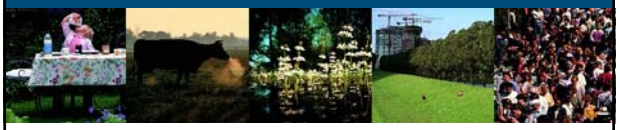
Questions?



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