Kasontwerp en energiezuinige kassystemen

Masterclass 26 november 2015 HAS Den Bosch
BOGO project "Klimaat en energie: nieuwe low input teeltsystem in de tuinbouw"

S. Hemming en F. Kempkes, Wageningen UR Glastuinbouw

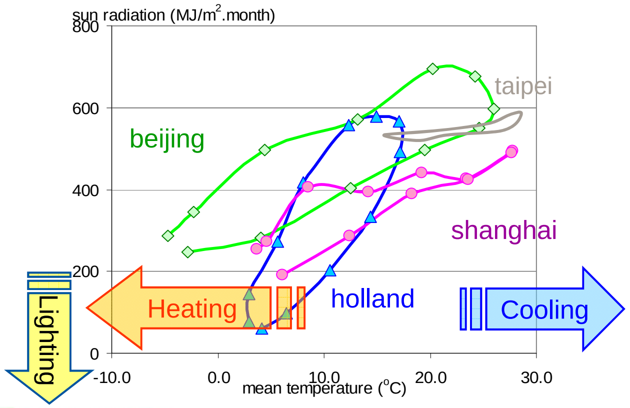
Sustainable greenhouse design

- Design greenhouse systems which combine (economic) production efficiency with minimal input of energy, water and nutrients for different regions in the world:

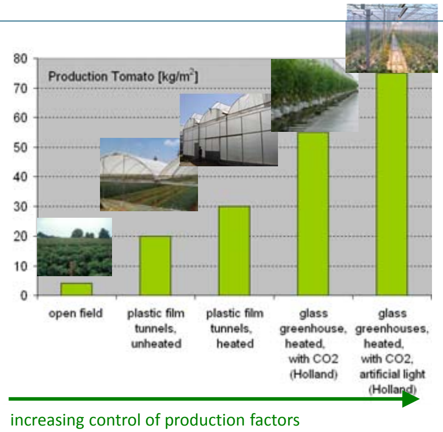
The "Adaptive Greenhouse" design

Sustainable greenhouse production

Climate conditions: different worldwide



Technology for greenhouse production



Technology for greenhouse production

- Controlability of production factors (light, CO_2, temperature, humidity, water&nutrients, pests&diseases)
- Degree of technology
- Knowlegde level of grower
- 24/7 attention of grower

→ greenhouse climate
→ crop response
→ economic result

Sustainable greenhouse production

- **Goals for design:**
- High production, product quality, predictability
- High energy efficiency and use of sustainble energy
- High water use efficiency, low nutrient losses
- Low pesticide use, high food safety
- Economic profit of the production system

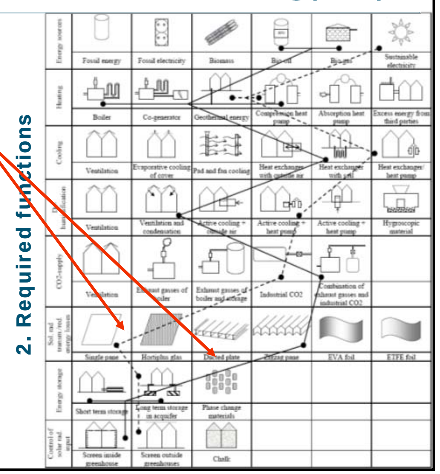
Design procedure

3. Alternative Working principles

1. Goals of design

4. Combination into Conceptual designs

5. Evaluation:
Experts
Model simulations
Practical experiments



Functions sustainable greenhouse design

- **Functions for design:**
  - Type of crop
  - …
  - …

Light
CO_2
Water & nutrients
Temperature
Humidity




Functions sustainable greenhouse design

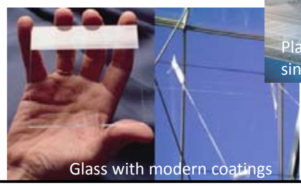
- **Functions for design:**
  - Greenhouse construction
  - …
  - …

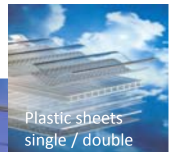
Make use of natural ventilation, it is for free!!!
Air exchange → temperature/humidity control
Air exchange → natural CO_2 supply

Functions sustainable greenhouse design

- **Functions for design:**
  - Covering material
  - …
  - …

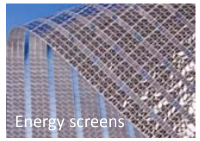
Make use of natural sunlight, it is for free!!!
Light → yield
Sun energy → energy saving

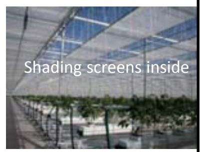


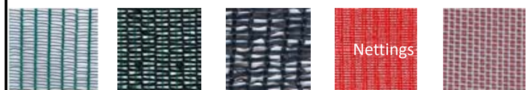


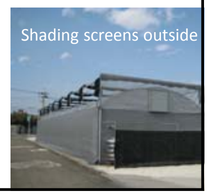
Functions sustainable greenhouse design

- **Functions for design:**
  - Shading and screens
  - …
  - …









Functions sustainable greenhouse design

- **Functions for design:**
  - "Cooling" system
  - …
  - …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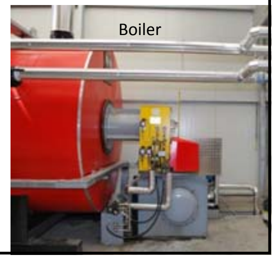
Functions sustainable greenhouse design

- **Functions for design:**
  - Heating system
  - …
  - …

Heat, CO_2, electricity



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Functions sustainable greenhouse design

- **Functions for design:**
  - Energy source and supply
  - …
  - …

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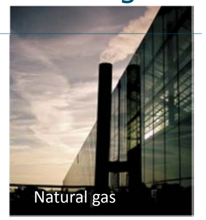
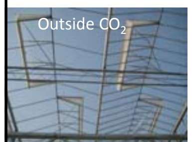
Functions sustainable greenhouse design

- **Functions for design:**
  - CO_2 supply
  - …
  - …

CO_2 = growth





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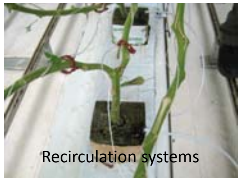
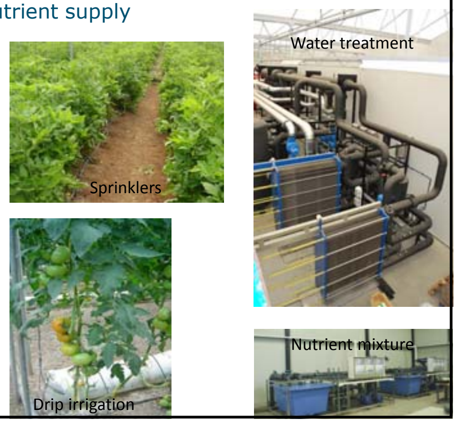
Functions sustainable greenhouse design

- **Functions for design:**
  - Growing systems and substrates
  - …
  - …

Functions sustainable greenhouse design

- **Functions for design:**
  - Water and nutrient supply
  - …
  - …





Functions sustainable greenhouse design

- **Functions for design:**
  - Pest and disease management
  - …
  - …

Find optimum greenhouse design

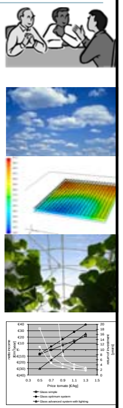
How to decide on optimum sustainable greenhouse design for different region's in the world?

Research methodology

Expert view
- Experts with long year experiences in different countries

Dynamic greenhouse climate and crop models
- input: local outside climate, crop parameters
- variables: greenhouse design, climate equipment, set points
- result: year-round inside greenhouse climate (temperature / humidity / CO_2) and crop performance at every hour of year

Economic model
- input: local prices for products, materials and investments, local interest rates
- output: return of investment, yearly net benefit



Hemming et al., 2008; Vanthoor, 2011

Research methodology

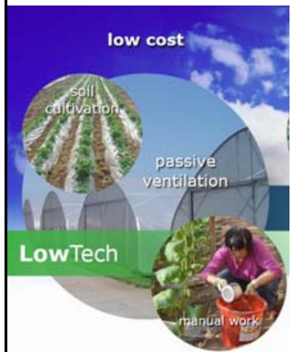
Resources: Land, Energy, Capital, Labour, Water, Nutrients

Climate: Temperature, Humidity, Solar Radiation, Wind, Rainfall

Market: Price of Products, Quality of Products, Legislation

→ **Adaptive greenhouse model** → **Greenhouse system design**

Sustainable greenhouse production

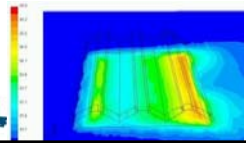


Example: low tech

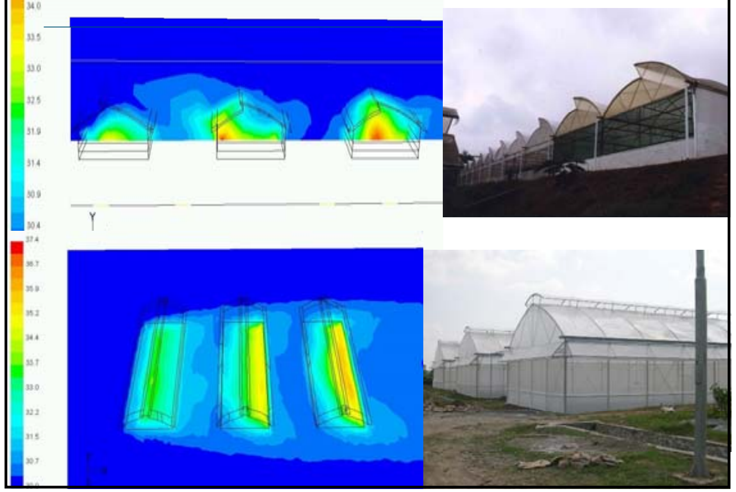
Example: Malaysia, tropical lowland multispan

Goal: Introduce a passive, low-cost, passive, greenhouse concept suitable for lowland tropical climate conditions



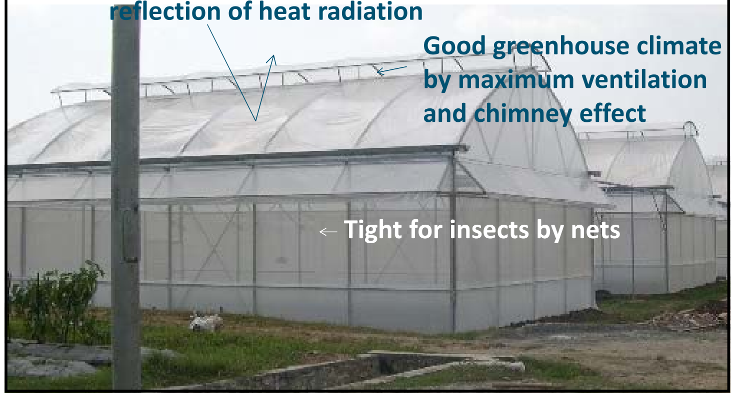



Example: Indonesia, tropical lowland

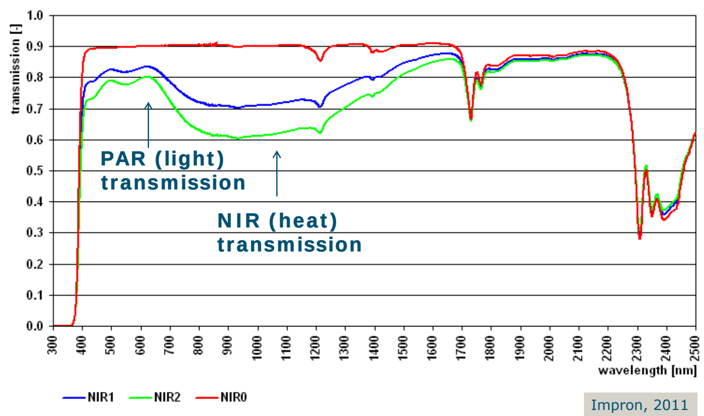


Example: Indonesia, tropical lowland

New plastic films:
high light transmission, diffuse,
reflection of heat radiation

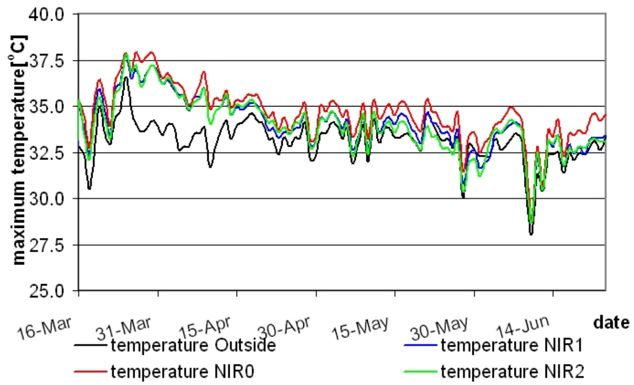


Example: Indonesia, covering material



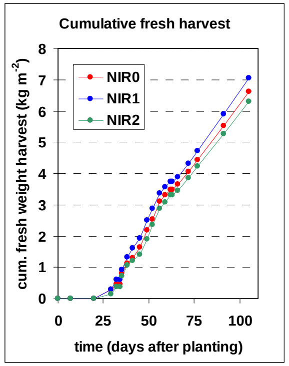
Impron, 2011

Example: Indonesia greenhouse climate



Impron, 2011

Example: Indonesia, crop production



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Impron, 2011

Sustainable greenhouse production

Example: mid tech

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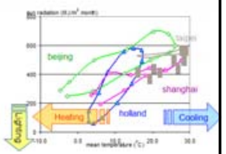
Realised demo greenhouse in Tainan, Taiwan



Goal: Introduce a medium-tech greenhouse concept with environmental control, soilless cultivation for safe tomato production

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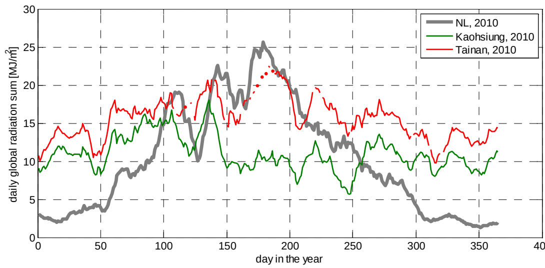
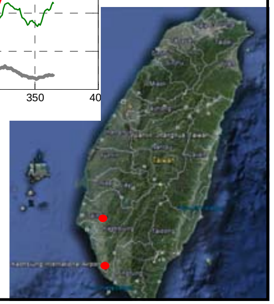
Hemming et al., 2013

Taiwan climate – global radiation





Typical:

- Year round daily radiation sum of 10-20 MJ/m^2
- Large difference in cloudiness per region

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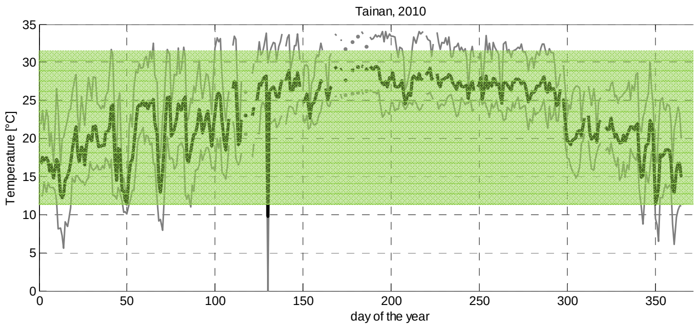
Hemming et al., 2013

Taiwan climate - temperatures

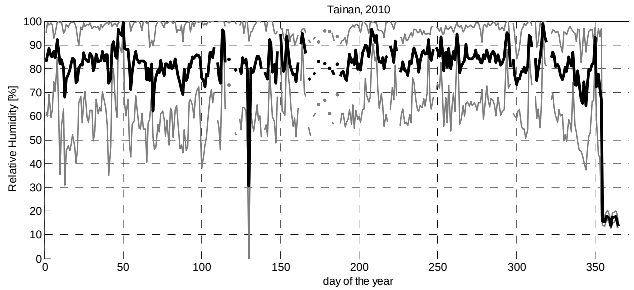


Typical:
-Heating demand small

Challenge:
- High temperatures create need for efficient ventilation
- Extra cooling measures needed

Hemming et al., 2013

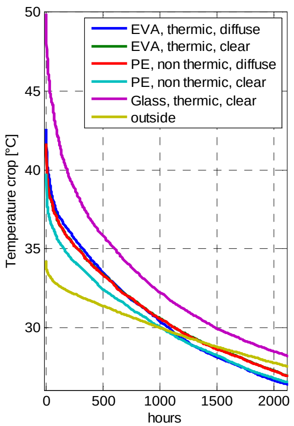
Taiwan climate - humidity



Challenge:
- High humidity levels can cause diseases of crops and low quality of products

Hemming et al., 2013

Light control – greenhouse covering

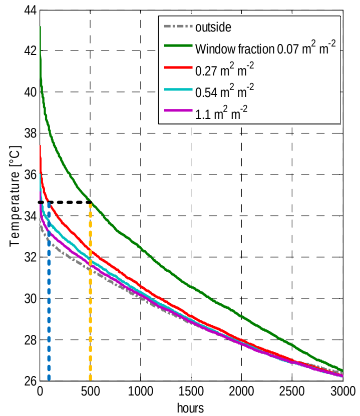


non-thermic plastic
→ lower night temperatures

diffuse plastic
→ higher crop production

Hemming et al., 2013

Temperature control – natural ventilation



Ventilation area > 30% brings temperature inside close to temperature outside

Hemming et al., 2013

Temperature control – natural ventilation

Window fraction [m² window / m² greenhouse]	Number of hours warmer than [h]		Number of hours with relative humidity higher than [h]		Evapo-transp. [kg/m²/yr]	Crop production [%]
	T air> 30°C	T air> 35°C	RH> 95%	RH> 90%		
0.07	1526	374	2197	5086	985	100
0.14	1231	157	2471	4906	1018	113
0.27	1057	41	2570	4676	1052	121
0.41	1004	18	2552	4522	1073	124
0.54	977	9	2520	4400	1087	126
1.1	943	1	2405	4176	1117	129

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Hemming et al., 2013

Cooling – with water - fogging

Adiabatic cooling = evaporation of water
Two functions:
1. decreases inside temperatures
2. increases humidity

BUT ventilation needed
NOT working at moments with too high humidity

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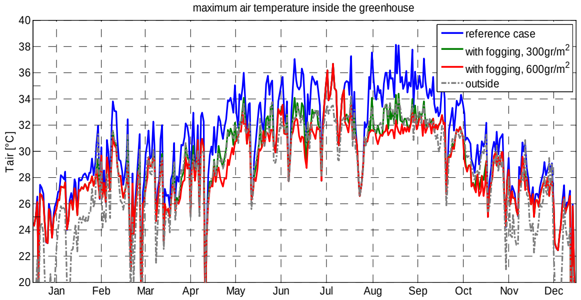
Temperature control – fogging



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Hemming et al., 2013

Temperature control - fogging

Fogging capacity [g/m²/h]	*# hours on*	*Number of hours warmer than 30°C [h]*		*Number of hours warmer than 35°C [h]*		*Number of hours with relative humidity higher than 95 or 90%*		*Evapo-transp [kg/m² /year]*	*Yearly fogging [kg/m²/ year]*
		T air	T crop	T air	T crop	90%	95%		
0	0	1174	1161	97	384	4263	2894	868	0
75	2328	1060	1139	35	344	4155	2839	841	137
150	2339	971	1124	16	316	4117	2801	824	242
225	2343	903	1112	3	289	4095	2802	811	318
300	2343	840	1096	0	259	4099	2800	800	374
375	2345	799	1091	0	241	4101	2801	794	410
450	2347	784	1086	0	230	4101	2804	790	432
525	2347	764	1085	0	225	4100	2804	788	445
600	2347	757	1085	0	217	4100	2804	787	452

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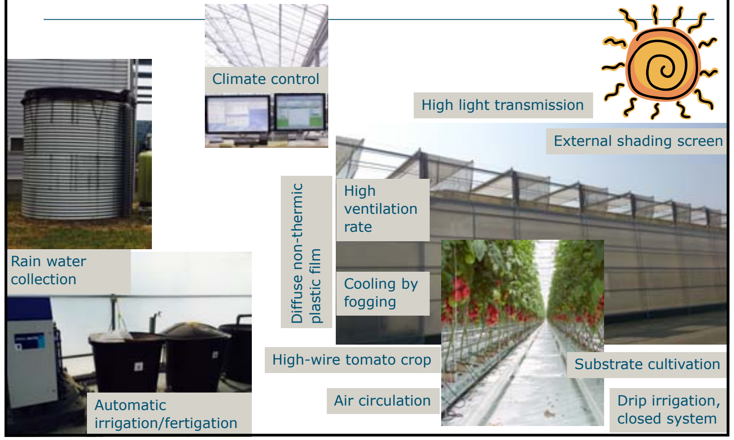
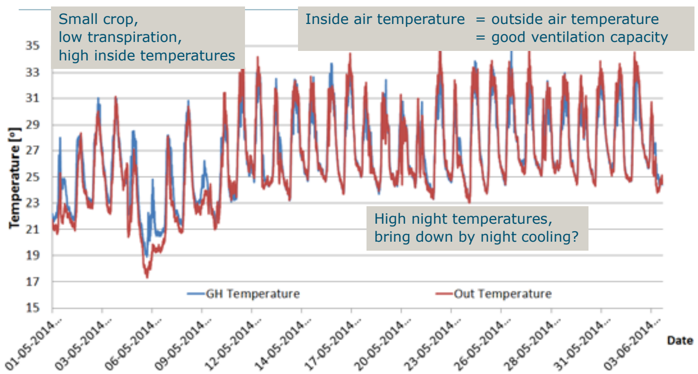
Example: Sustainable tomato greenhouse concept for sub-tropical areas



Realisation demo greenhouse

Temperature demo greenhouse



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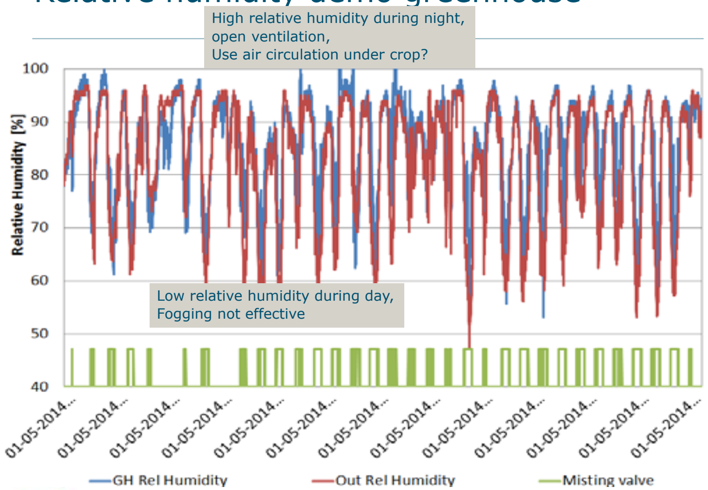
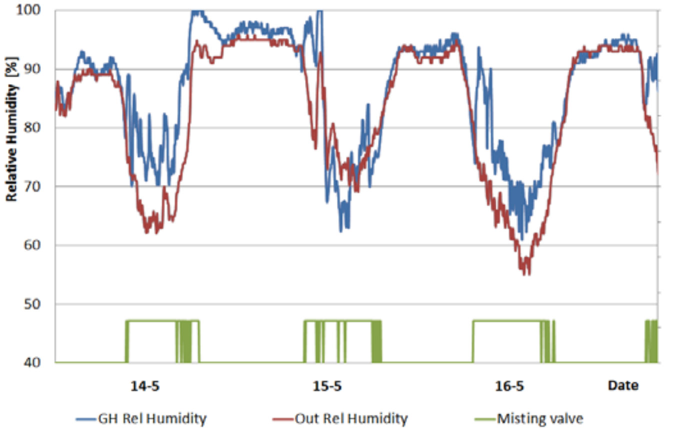
Relative humidity demo greenhouse



Fogging demo greenhouse



Fogging demo greehouse

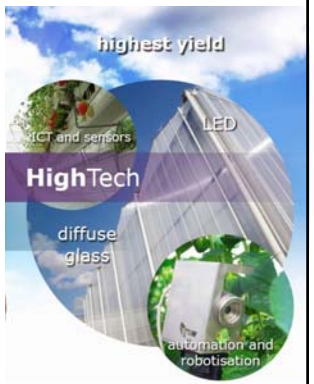
Fogging duration, puls interval, droplet size - ventilation open – sensor position

Possibilities of dehumidification

- Possibilities of decreasing humidity in greenhouse with natural ventilation:
  - Create air movement → avoid condensation on crop → use fans, air ducts under crop
  - Water system avoiding high evaporation → drip irrigation
  - Heating & ventilation → dry air
  - Cooling & condensation → dry air

Sustainable greenhouse production

Example: high tech - Energy saving -



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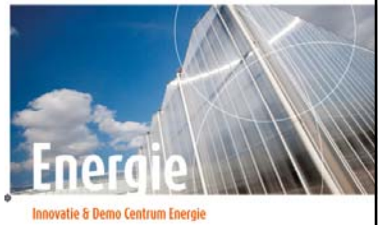
Innovation and Demonstration Centre (IDC) Energy

- **What:** innovations for energy saving in greenhouse production by new technologies and new cropping strategies
- **Who:** Wageningen UR, greenhouse supply industry, grower



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VenLowEnergykas

Goal: Greenhouse concept with high**est** energy saving and **good** tomato production

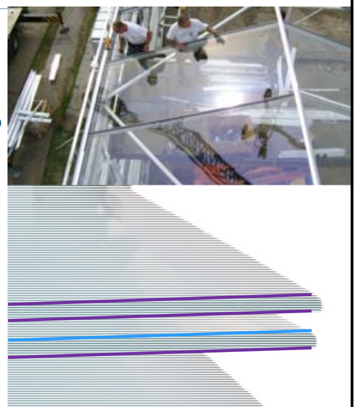
- Double glass with low u-value and high light transmission
- Mechanical dehumidification with heat-regain
- "Next Generation Cultivation Strategies" (climate control)

WAGENINGEN UR For quality of life — maurice, BOAL, Climeco, solar glass, Scheuten

VenLowEnergykas – double glass

- Double glass
- low u-value due to low-ε coating
- high light transmission due to AR coating

Glass	Coating	T..	U-value
Single	-	82	6.7
Single	AR-AR	91	
Single	AR-Low-ε	81	
Double	AR-AR-Low-ε-AR	79	1.2



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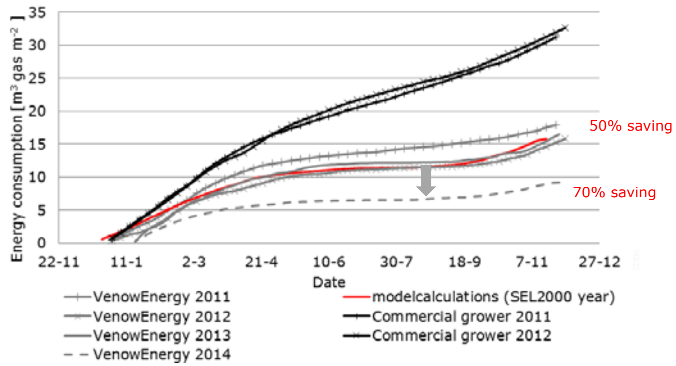
Hemming et al. 2012

VenLowEnergykas: energy consumption



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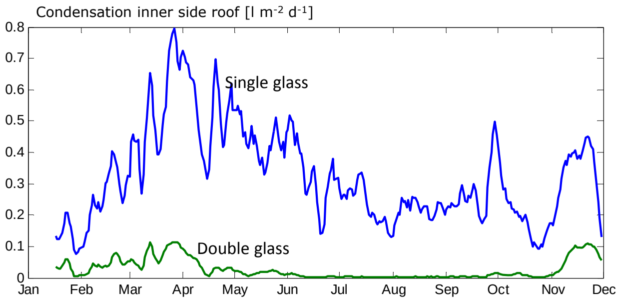
Kempkes et al. 2014

Dehumidification – condensation effect

De Zwart et al. 2015



Compensation necessary by:

- Ventilation
- Mechanical dehumidification
  (+ heat exchanger for sensible heat collection)
  (+ cold surface for latent heat collection)

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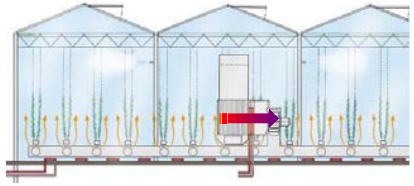
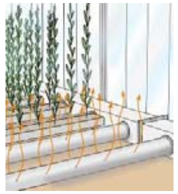
Dehumidification

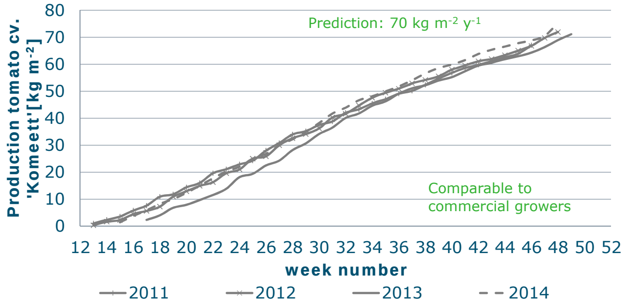
Ventilator & Heat exchanger



Blow in dry outside air
Perforated tubes



VenLowEnergykas: crop production tomato (cv. 'Komeett')



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Kempkes et al. 2014

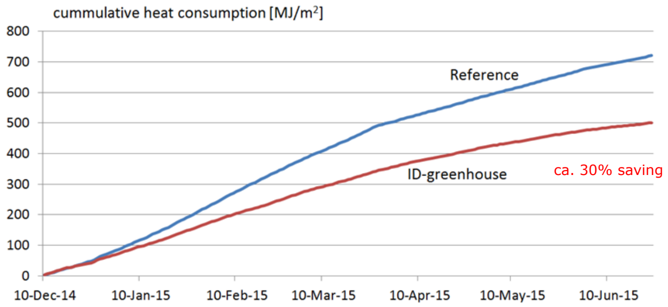
VenLowEnergykas: upscaling to practice

- ID Kas®
- Duijvestijn tomato grower
- High insulation with double glass with AR coating and diffuse structure (no low-ε coating)
- "Next Generation Cultivation Strategies"

Duijvestijn Tomaten

BOAL SYSTEMEN
TECHNOKAS
solar | glass
Scheuten

IDkas® at Duijvestijn Tomato



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De Zwart et al. 2015

2SaveEnergykas®

Goal: Greenhouse concept with **high** energy saving and **high** production at **limited** level of investment

- New Venlo-greenhouse with insulated covering
- Glass with AR coating and diffuse F-CLEAN® inside for insulation and high light level
- Small ventilation windows
- "Next Generation Cultivation Strategies" and dehumidification

WAGENINGEN UR For quality of life | VAN DER VALK | BOAL SYSTEMEN | VDH | AGC

2SaveEnergykas®: glass & F-CLEAN®

- Glass
- F-CLEAN®
- always 1 layer diffuse

WAGENINGEN UR For quality of life

Kempkes et al. 2015

2SaveEnergykas®: light transmission

Kempkes et al. 2015

Hemispherical transmission τ_h and the haze η of different base materials for PAR light 400- 700 nm

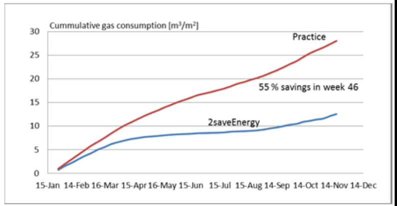
Material	Haze η	Hemispherical light transmission τ_h
glass clear	0	82.1
glass clear + AR coating	0	90.5
Fclean clear	0	87.4
glass diffuse high haze	68	82.1
glass diffuse high haze + AR coating	68	88.8
Fclean diffuse	77	84.5

Hemispherical transmission τ_h and the haze η of different combination of materials for PAR light 400- 700 nm

Material	Haze η	Hemispherical light transmission τ_h
glass clear + Fclean diffuse	77	72.6
glass clear + AR coating + Fclean diffuse	77	75.9
glass diffuse high haze + Fclean clear	68	75.3
glass high haze + AR coating + Fclean clear	68	80.7

2SaveEnergykas®: energy consumption

- Predicted in a whole year: 19 m^3 gas m^{-2} y^{-1} (ca. 40% saving compared to practice)
- Realisation 14 m^3 gas m^{-2} y^{-1} (ca. 55% saving compared to practice),
  start ca. 3 weeks delayed
  climate 2015 differs from calculation year
- Commercial growers large differences: 24-35 m^3 in week 45



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Kempkes et al. 2015

2SaveEnergy kas®: crop production tomato cv. 'Cappricia'

- Predicted in a whole year: 63 kg m^{-2}
- Realisation around 65 kg m^{-2} (start ca. 3 weeks delayed)

WAGENINGEN UR

Kempkes et al. 2015

Summary: Sustainable greenhouse production – a matter of design & coverings

WAGENINGEN UR

Ministerie van Economische Zaken