

## New technologies developed for conventional growing systems: possibilities and limitations for application in organic systems.

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## Outline

- Introduction
- Water use efficiency/ reduced water use
- Energy use efficiency/ reduced CO<sub>2</sub> emission
- Some new techniques and concepts
- Final remarks

## Acknowledgements

- Colleagues: Arie de Gelder, Silke Hemming, Erik van Os, Wim Voogt, Jos Balendonck, Marcel Raaphorst
- Organisations: Ministry of Agriculture, Product Board of Horticulture and research Programme Greenhouse as Energy Source

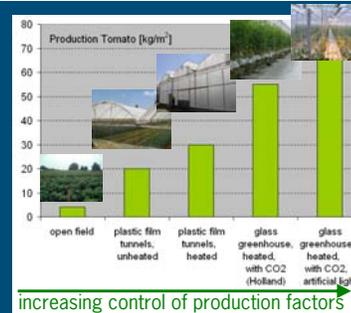


## Challenges for Future Vegetable production:

- (Twice as much) with less ecological footprint
- Economically viable



## Twice as much: better controlled conditions



## Reducing the ecological footprint (planet)

Optimize efficiency of (minimal) inputs:

- Energy
- Water, minerals } (Planet)
- Crop protection
- Labour } (People)

within (economic) constraints ■ Profit

- Economically viable



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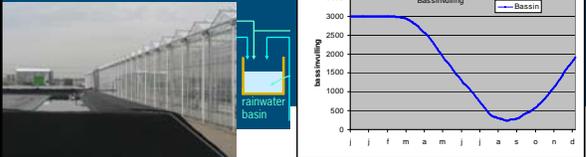
### Water sources

- Rainwater
  - Very Low Chemicals
- Tapwater
  - Salts
- Surface water
  - Salts, pathogens, chemicals
- Groundwater
  - Salts
- Condensation water
  - Very Low Chemicals




### Optimal use of current techniques : Sustainable water use

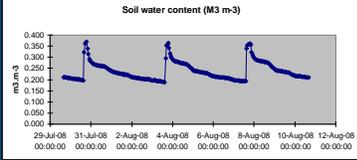
Rainwater storage	rainwater	additional water
■ 500 m <sup>3</sup> /ha	43%	57
■ 1500	63	37
■ 3000	97	3




### Efficient irrigation/ fertilization strategies

Sensor technology and combination of (soil) physics and physiological information






### Efficient irrigation/ fertilization strategies





Lysimeters      Robust tensiometer

Water content meters



### Water Use Efficiency: irrigation based on soil water content

Crop	Water Use traditional (mm)	Water Use optimized (mm)	Marketable WUE (kg/m <sup>3</sup> )	Water Saving Index (%)
Ornamentals (Italy)	540	413		24
Cucumber (Turkey)	717	545	44 (35)	19
Tomato (Jordan)	425	275	8 (6)	25
Egg plant (Lebanon)	95	71	54 (36)	35
Lettuce (Netherlands)	186	66	73 (22)	69

From Balendonck et al., FlowAid



### Outline

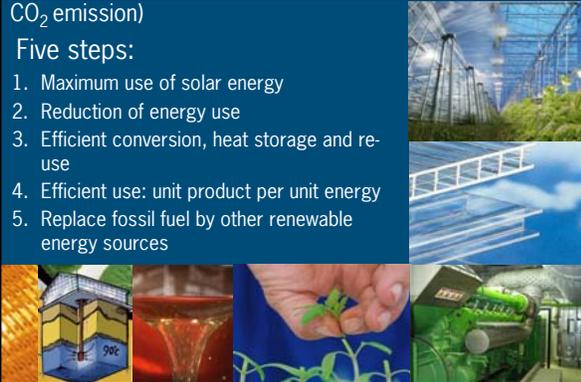
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### Reduction of Carbon footprint: reduction energy use (i.e. CO<sub>2</sub> emission)

Five steps:

1. Maximum use of solar energy
2. Reduction of energy use
3. Efficient conversion, heat storage and re-use
4. Efficient use: unit product per unit energy
5. Replace fossil fuel by other renewable energy sources

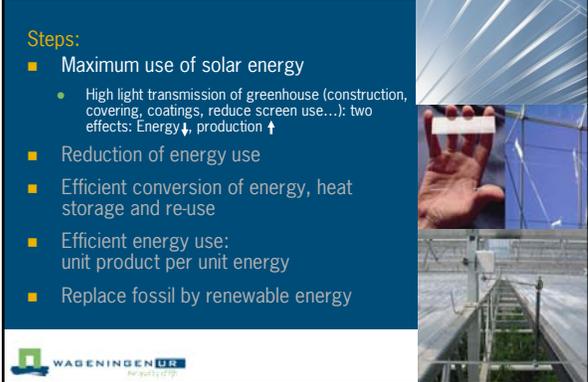


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### Reduction of Carbon footprint

Steps:

- Maximum use of solar energy
  - High light transmission of greenhouse (construction, covering, coatings, reduce screen use...): two effects: Energy ↓, production ↑
- Reduction of energy use
- Efficient conversion of energy, heat storage and re-use
- Efficient energy use: unit product per unit energy
- Replace fossil by renewable energy

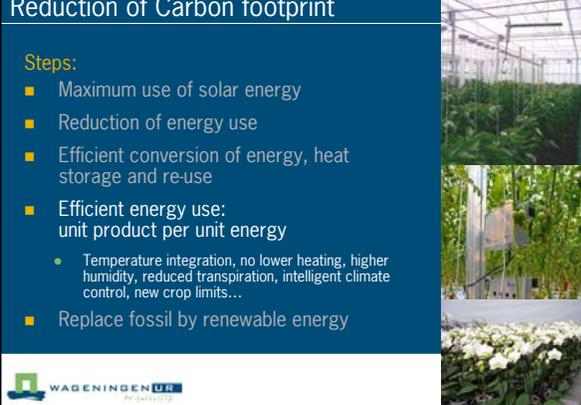


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### Reduction of Carbon footprint

Steps:

- Maximum use of solar energy
- Reduction of energy use
- Efficient conversion of energy, heat storage and re-use
- Efficient energy use: unit product per unit energy
  - Temperature integration, no lower heating, higher humidity, reduced transpiration, intelligent climate control, new crop limits...
- Replace fossil by renewable energy

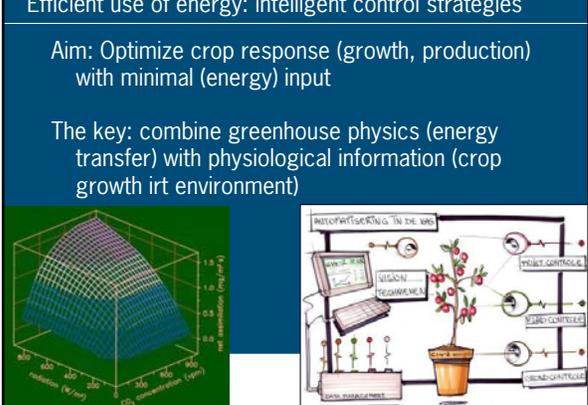


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### Efficient use of energy: intelligent control strategies

Aim: Optimize crop response (growth, production) with minimal (energy) input

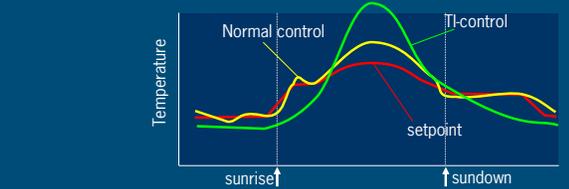
The key: combine greenhouse physics (energy transfer) with physiological information (crop growth in environment)



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### Intelligent control strategies: T- Integration

- Temperature: main factor determining energy use (75-90%)



- Temperature Integration: Principle: crop production related to average temperature  
Energy saving: up to 10% lower temperature during heating higher temperature during sunlight

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### Optimal integration of techniques: new growing concept tomato

Target: 60 kg tomato with 26 m<sup>3</sup> gas

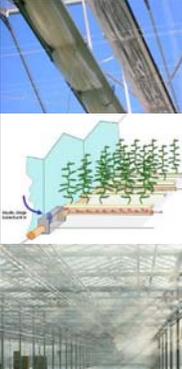
- high insulation (single glass + 2 screens)
  - transparent screen closed until 250 W/m<sup>2</sup>
  - energy screen closed when T<sub>outside</sub> < 8°C
- 1°C lower heating temperature
- Increased ventilation set point → more CO<sub>2</sub>
- Active cooling
- Humidity set point ventilation > VPD 1.5g/m<sup>3</sup>, air circulation
- External CO<sub>2</sub>



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### New growing concepts Cucumber and Sweet Pepper

- Double/Triple energy screens
  - XLS 18 Firebreak ( 72 %)
  - XLS 10 Ultra Revolux (47 %)
  - December-February AC foil (EH foil removed to AC)
- Crop ventilation with outside-air to control humidity
- High pressure mist/ evaporative cooling system
- External CO<sub>2</sub>



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### Production of Cucumber (2009)

Crop	10 cm slab		
	Kg/m <sup>2</sup>	number/m <sup>2</sup>	Fruit Weight (gram)
1	25.1	58.4	430
2	27.2	57.8	471
3	21.0	48.0	438
Total	73.3	164.2	446

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### Overview results new growing concepts 2008-2010

Crop	Goal	Results	CO <sub>2</sub> footprint
		<b>Production kg/m<sup>2</sup></b>	<b>CO<sub>2</sub>/kg</b>
Cucumber (08)	80	73	
Tomato (09/10)	60/65	68/70	Ca 0.6
Sweet Pepper (10)	32	30 (prognosis)	( = 50% compared to normal)
		<b>Energy m<sup>3</sup>/ha</b>	<b>gas (l m<sup>3</sup> = 31.6 MJ)</b>
Cucum/Tomato	26/25	25	
Sweet Pepper	20	22 (prognosis)	

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### New techniques and concepts

#### Diffuse light

	reference	low haze	high haze
Spring crop		+6.5%	+9.2%
54.4 Kg/m <sup>2</sup>		57.9	59.4
Autumn crop 2008		+8.8%	+9.7%

No light loss      3% less light

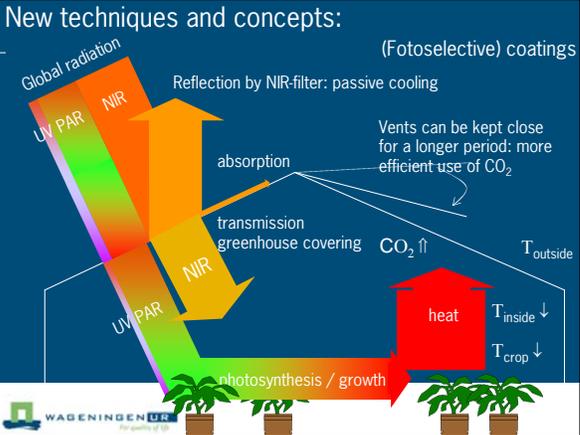


Hemming et al.

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### New techniques and concepts:

(Fotoselective) coatings



Global radiation: UV, PAR, NIR

Reflection by NIR-filter: passive cooling

absorption

transmission greenhouse covering

CO<sub>2</sub> ↑

photosynthesis / growth

heat

T<sub>inside</sub> ↓

T<sub>crop</sub> ↓

T<sub>outside</sub>

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### New techniques and concepts

(Semi) closed/ completely controlled greenhouses:

- No or minimum ventilation openings
- Independent control of Temperature, humidity and CO<sub>2</sub>
- Water recovery
- Less crop protection
- Higher CO<sub>2</sub> concentration, production increase (to 10-20%)
- Energy saving (+30%)



• Bijl door marcel

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### Semi-closed greenhouses



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### Effects active cooling on CO<sub>2</sub> concentration



Supply capacity: 230 kg CO <sub>2</sub> ha <sup>-2</sup> h <sup>-1</sup>	Open greenhouse	Semi-closed (150 W/m <sup>2</sup> )	Semi-closed (350 W/m <sup>2</sup> )	Completely closed greenhouse
CO <sub>2</sub> concentration (ppm)	600	730	950	1100
CO <sub>2</sub> supplied (kg/m <sup>2</sup> /y)	54.7	46.1	29.6	14.4

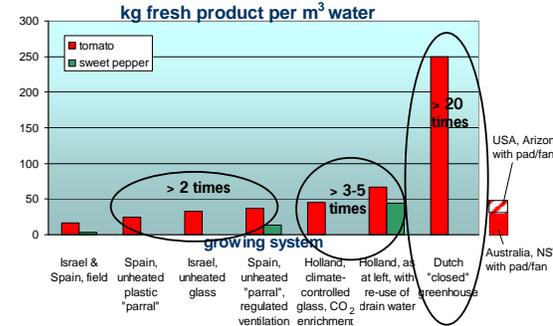
■ Increased CO<sub>2</sub> concentrations → 10-20% higher yield

Quian, 2008

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### Water use efficiency greenhouses

kg fresh product per m<sup>3</sup> water



growing system

- Israel & Spain, field
- Spain, unheated plastic "parral"
- Israel, unheated glass
- Spain, unheated "parral", regulated ventilation
- Holland, climate-controlled glass, CO<sub>2</sub> enrichment
- Holland, as at left, with re-use of drain water
- Dutch "closed" greenhouse
- Australia, NSW with pad/fan
- USA, Arizona with pad/fan

Stanghellini

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### Exploring new techniques and concepts

■ Innovation and Demo Centrum IDC: three demo greenhouses (500m<sup>2</sup> each):



- Flowdeck
- ZonWind
- Sunergy

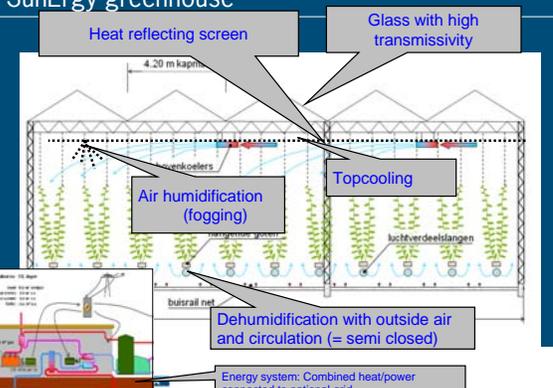
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Van der Waag

Productieschap Tuitouwe

Ministerie van Landbouw, Natuur en Voedselwacht

### SunErgy greenhouse



- Heat reflecting screen
- Glass with high transmissivity
- 4.20 m kapiteel
- ventilatoren
- Air humidification (fogging)
- Topcooling
- buistrail net
- Dehumidification with outside air and circulation (= semi closed)
- Energy system: Combined heat/power connected to national grid

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### Results SunErgy Greenhouse

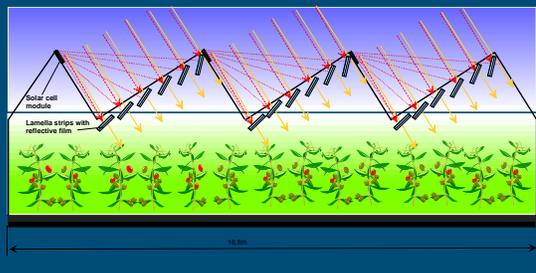


**Cucumber (5 months):**  
 > 50 kg/m<sup>2</sup>, almost no Botrytis, net use: 1.2 m<sup>3</sup>/m<sup>2</sup>

**Tomato: 76.2 kg/m<sup>2</sup>, energy < 16 m<sup>3</sup>/m<sup>2</sup> (60% saving)**

**Pepper: prognosis: 32kg/m<sup>2</sup>, 25 m<sup>3</sup>/m<sup>2</sup>**

### Second generation Electricity producing greenhouses



Solar cell module

Lambolla strips with reflective film

16.00

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### Exploring new techniques and concepts :

Advanced sensor technology: Multiple Imaging Plant Stress: MIPS as early warning system

- Multiple chlorofyl fluorescence, colour, Infra red
- imaging time samples
- Plant leaf, plant, crop
- Stress biotic en a-biotic



chlorofyl fluorescence    colour    IR

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### Exploring new techniques and concepts:

- Combination of organic greenhouses and other organic (agro) activities (e.g. livestock farming, fish, )
  - Alternative sources of CO<sub>2</sub>, heat, minerals, waste



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Integrated crop protection

Intelligent water and nutrient saving irrigation

Complete control environmental conditions

Additional elements in tomorrows organic protected cultivation?

Sustainable energy sources 90%

Advanced sensing techniques

Crop response based environmental control

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