New Techniques For Sustainable Greenhouse Vegetable Production

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WAGENINGEN UR

Outline

- Introduction
- Optimal integration of existing techniques
- Exploring new techniques and concepts
- Practical steps and guidelines

Acknowledgements

- Collegues: Arie de Gelder, Silke Hemming, Pierre Ramakers, Tom Dueck, Erik van Os
- Organisations: Ministry of Agriculture, Product Board of Horticultue and research Programme Greenhouse as Energy Source

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Sustainability: the capacity to endure

Meeting the needs of the present generation without compromising the ability of future generations to meet their needs

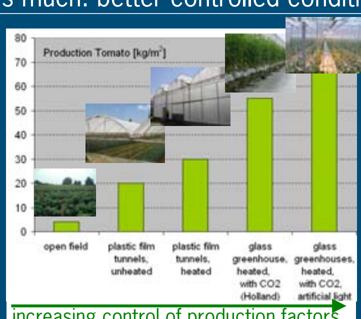
(Bruntland 1987)

Pictue: nasa

Challenges for Sustainable Vegetable production:

- Twice as much with half the ecological footprint
- Economically viable

Twice as much: better controlled conditions



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Half the ecological footprint (planet)

Optimize efficiency of (minimal) inputs:

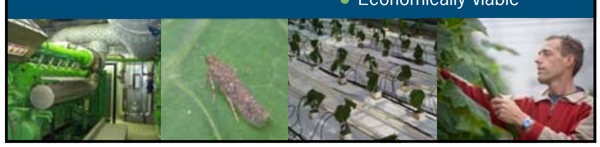
- Energy
- Water, minerals
- Crop protection
- Labour

} (Planet)

(People)

within (economic) constraints

- Profit
  - Economically viable



Ecological footprint (example yearround tomato, nl)

Item	Quantity/m²	Quantity/kg
Yield	Ca 60 kg	
Fertilisers kg (recirculation system)	1.6 kg	27 g
1 Uptake K	0.2000 g	3,4
2 Uptake N	0.1200 kg	2 g
3 Uptake P	0.0325 kg	0,5 g
Chemicals (active components / IPM)	0.4-0.8 gram	0,01 g
Electricity kWh	7 (25MJ/ 60MJ$_p$)	0.4MJ/1MJ$_p$) (= 0.06 kg CO_2)
Natural gas use m³	43-44 (1350 MJ)	22,5 MJ (= 1.3 kg CO_2)
Water l	800 l	13,5 l

1 MJ = +/- 1000 Btu

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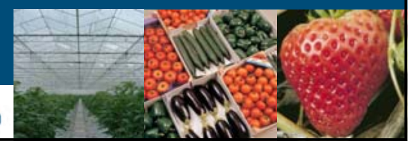
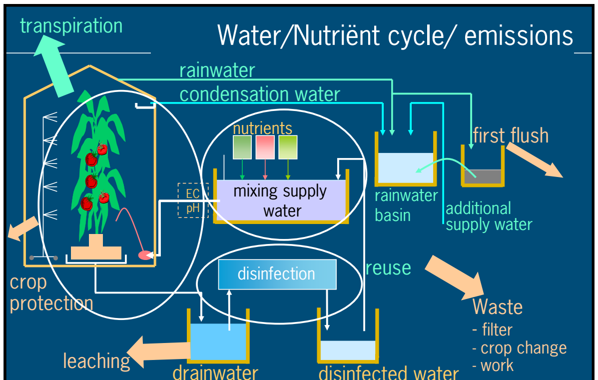
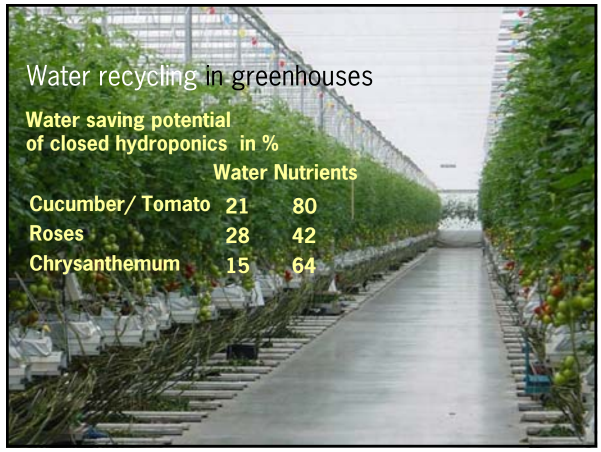


Water/Nutriënt cycle/ emissions



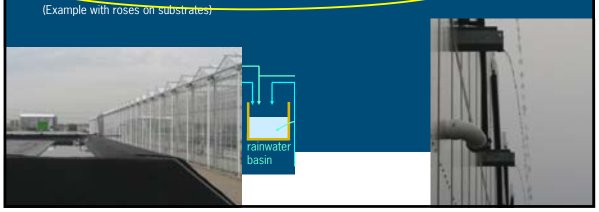
Erik van Os, WUR Greenhouse Horticulture



Optimal use of current techniques : Sustainable water use

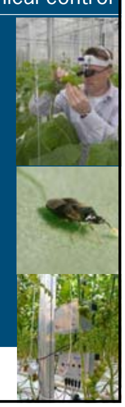
Rainwater storage	rainwater	additional water
500 m³/ha	43%	57
1500	63	37
3000	97	3

(Example with roses on substrates)



Optimal use current techologies: reduce chemical control

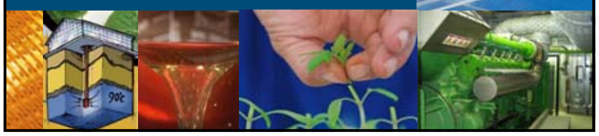
- Growing in substrates
- New pesticides (less persistent, less toxic, more selective)
- Better climate control (fungal diseases)
- Resistant varieties / rootstocks (soil-borne diseases)
- Innovative spraying technologies
- Supervised pest control (crop scouting: damage/action thresholds)
- Biological pest control (replacement of chemicals, selective pesticides)
- Integrated Pest Management



Optimal use of current techniques: Reduction of Carbon footprint (reduction energy use)

Five steps:

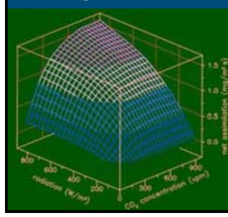
1. Maximum use of solar energy
2. Reduction of energy use
3. Efficient conversion, heat storage and re-use
4. Efficient use: unit product per unit energy
5. Replace fossil fuel by other renewable energy sources

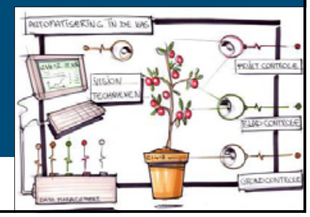


Efficient use of energy: intelligent control strategies

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

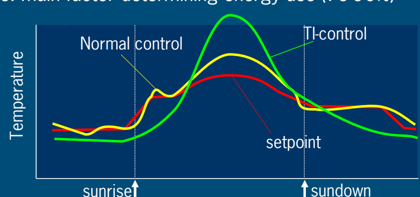
The key: combine greenhouse physics (energy transfer) with physiological information (crop growth irt environment)





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

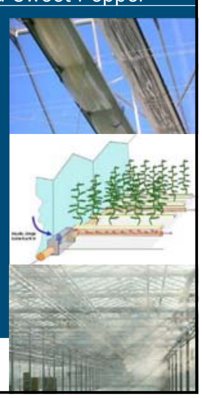
Optimal integration of existing techniques: new growing concept tomato

Target: 60 kg tomato with 26 m³ gas= 1150 MJ

- high insulation (single glass + 2 screens)
  - transparent screen closed until 250 W/m²
  - energy screen closed when $T_{outside}$< 8°C
- 1°C lower heating temperature
- Increased ventilation set point → more CO_2
- Active cooling
- Humidity set point ventilation > VPD 1.5g/m³, air circulation
- External CO_2

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_2



Overview results new growing concepts 2008-2010

	Goal	Results	CO_2 footprint
Crop	Production kg/m²		CO_2/kg
Cucumber (08)	80	73	
Tomato (09/10)	60/65	68/70	Ca 0.6
Sweet Pepper (10)	32	30 (prognosis)	(= 50% compared to normal)
	Energy m³ nat gas (1 m³ = 31.6 MJ)		
Cucum/Tomato	26/25	25	
Sweet Pepper	20	22 (prognosis)	

Sustainability and profit

Comparison of different protected cropping systems

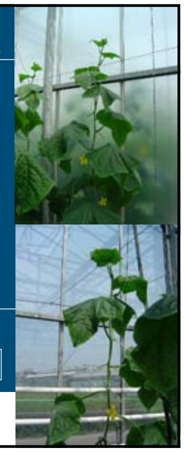
	Glass standard	Glass with CO2	Glass with fogging	Glass with CO2 & fogging	Glass with CO2 & fogging & closed watersystem	Glass CO2 & fogging & closed watersystem & lighting	Glass with CO2 & fogging & closed watersystem & insect nets & screens
Use of resources:							
Water consumption [kg produce/m3]	28.3	41.6	27.1	38.4	49.4	62.5	51.9
Energy (heat) consumption [MJ/kg]	14.7	9.9	14.5	9.7	9.7	4.5	9.2
Produce less environmental loads:							
CO2 application per unit produce	zero	high	zero	medium	medium	high	medium
Nutrient emissions	high	high	high	high	low	low	low
Pesticides applied per unit produce	high	high	high	medium	medium	medium	low
Efficiency of production process:							
Yield per area [kg/m2]	36.0	53.3	36.4	54.7	54.7	68.9	57.5
Profit per area and year [€/m2/year]	€ 6.90	€ 14.87	€ 6.74	€ 15.58	€ 15.62	€ (2.40)	€ 16.58
Return of investment [years]	4.3	3.0	4.4	3.0	3.1	7.9	3.0

Example for tomato growing in Turkey, Hemming ea, 2010

Exploring new techniques and concepts

Diffuse light

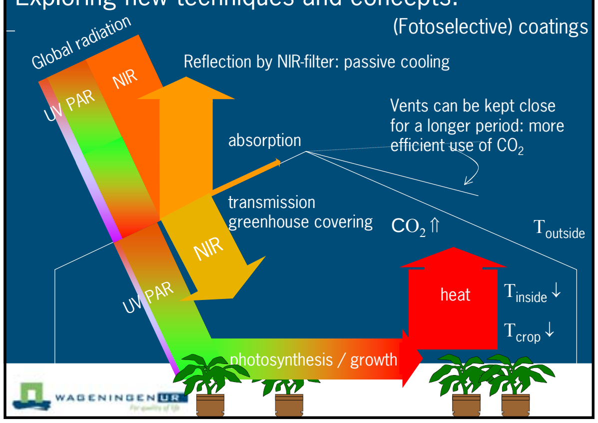
	reference	low haze 27%	high haze 74%
Spring crop 54.4 Kg/m^2		+6.5% 57.9	+9.2% 59.4
Autumn crop 2008		+8.8%	+9.7%
		No light loss	3% less light



Hemming et al.

Exploring new techniques and concepts:

(Fotoselective) coatings



Exploring new techniques and concepts

(Semi) closed/ completely controlled greenhouses:

- No or minimum ventilation openings
- Independent control of Temperature, humidity and CO_2
- Water recovery
- Less chemical crop protection
- Higher CO_2 concentration, production increase (to 10-20%)
- Energy saving (+30%)

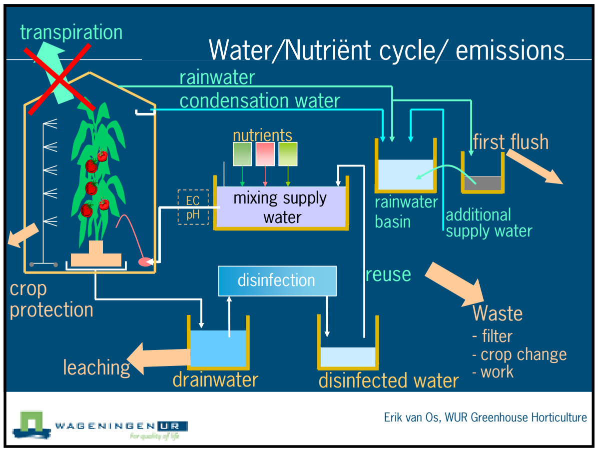
Semi-closed greenhouses

Effects active cooling on CO_2 concentration

Supply capacity: 230 kg CO_2 ha^{-2} h^{-1}	Open greenhouse	Semi-closed (150 W/m^2)	Semi-closed (350 W/m^2)	Completely closed greenhouse
CO_2 concentration (ppm)	600	730	950	1100
CO_2 supplied (kg/m^2/y)	54.7	46.1	29.6	14.4

- Increased CO_2 concentrations → 10-20% higher yield

Quian, 2008


Water/Nutriënt cycle/ emissions
transpiration
rainwater
condensation water
nutrients
mixing supply water
EC
pH
first flush
rainwater basin
additional supply water
disinfection
reuse
crop protection
leaching
drainwater
disinfected water
Waste
- filter
- crop change
- work
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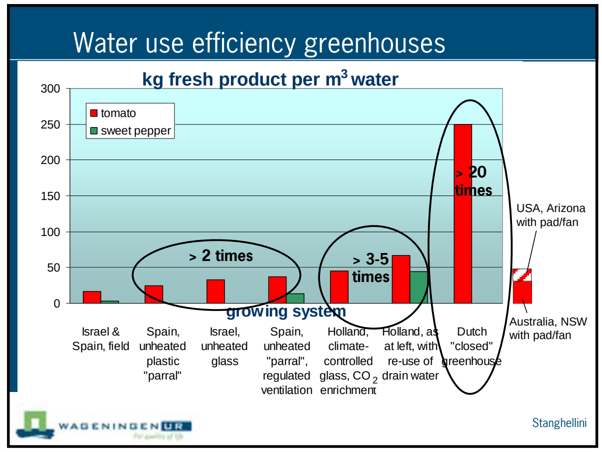
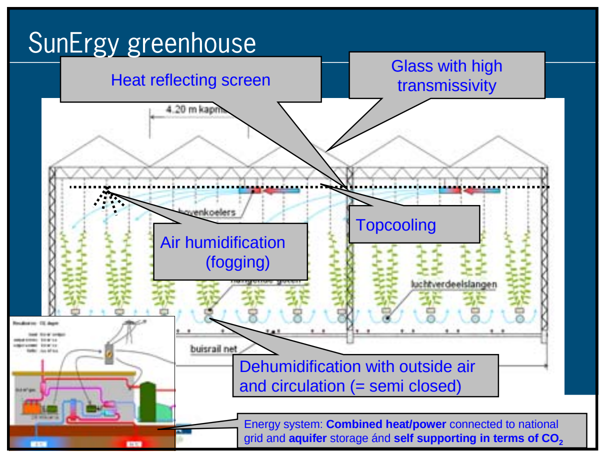
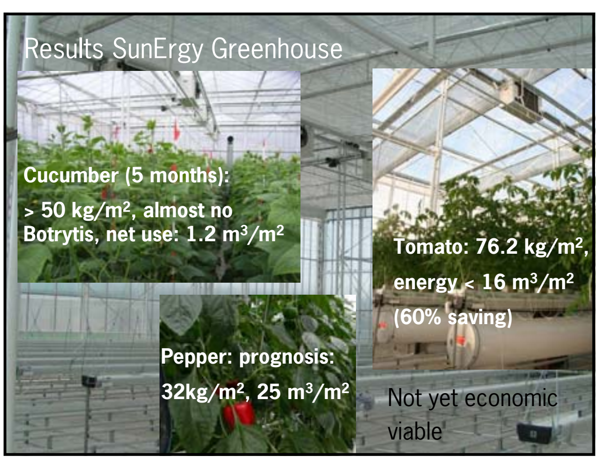
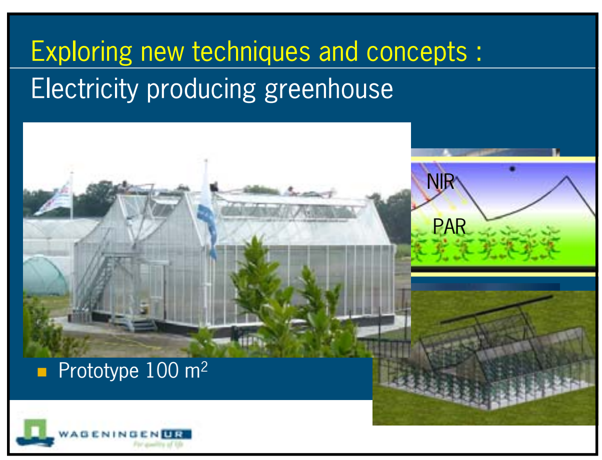

Water use efficiency greenhouses
kg fresh product per m³ water
tomato
sweet pepper
> 2 times
> 3-5 times
> 20 times
USA, Arizona with pad/fan
Australia, NSW with pad/fan
growing system
Israel & Spain, field
Spain, unheated plastic "parral"
Israel, unheated glass
Spain, unheated "parral", regulated ventilation
Holland, climate-controlled glass, CO2 enrichment
Holland, as at left, with re-use of drain water
Dutch "closed" greenhouse
Stanghellini

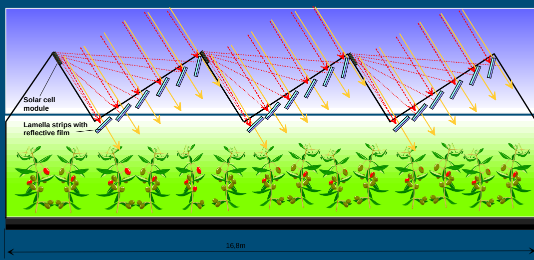

Exploring new techniques and concepts
Innovation and Demo Centrum IDC: three demo greenhouses (500m² each):
ZonWind
Sunergy
Flowdeck
Productschap Tuinbouw


SunErgy greenhouse
Heat reflecting screen
Glass with high transmissivity
Topcooling
Air humidification (fogging)
Dehumidification with outside air and circulation (= semi closed)
Energy system: Combined heat/power connected to national grid and aquifer storage and self supporting in terms of CO2


Results SunErgy Greenhouse
Cucumber (5 months):
> 50 kg/m², almost no Botrytis, net use: 1.2 m³/m²
Tomato: 76.2 kg/m², energy < 16 m³/m² (60% saving)
Pepper: prognosis: 32kg/m², 25 m³/m²
Not yet economic viable

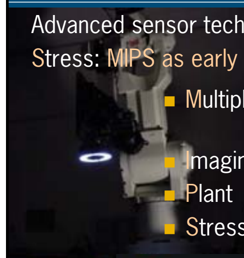

Exploring new techniques and concepts :
Electricity producing greenhouse
NIR
PAR
Prototype 100 m²

Second generation Electricity producing greenhouses



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

Exploring new techniques and concepts :

- Combination of greenhouses and other (agro) activities (e.g. livestock farming, urban enviroment)
  - Re-use of CO_2, heat, minerals, waste

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- Practical steps and guidelines for the new growing concept to reduce the Carbon Footprint

7 Practical steps and guidelines

- Humidity control by active ventilation
- Insulation to reduce heat loss
- Grow with the season
- Controlled air movement
- Air humidification
- Active cooling
- Heat storage in aquifer