

Energy saving in greenhouse horticulture - towards fossil fuel free greenhouses in the future

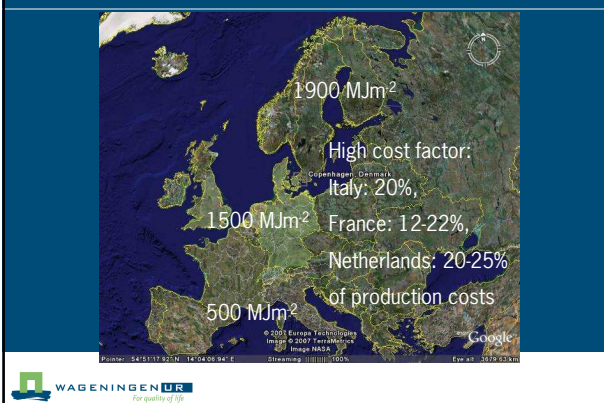
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GLASTUINBOUW

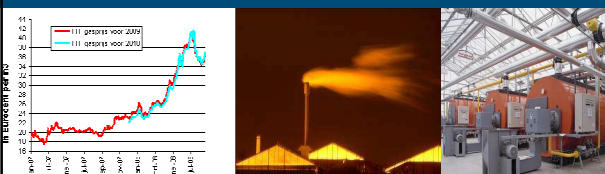
Energy use in European greenhouse horticulture

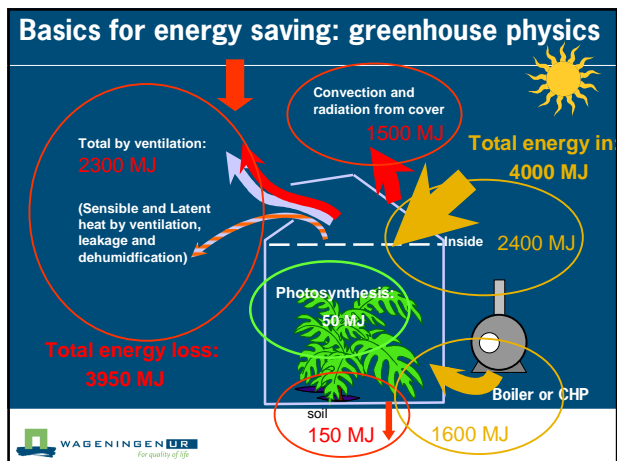


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Reduction of fossil energy use

- Energy: 20-30% of production costs
- Targets Greenhouse sector in the Netherlands for 2020:
 - -48% CO₂ emission compared to 1990
 - New build greenhouses operate (almost) without fossil fuel
 - Greenhouse sector produces sustainable energy (heat and electricity)





Towards fossil fuel free greenhouses

- 1: Maximal use of solar energy
- 2: Reduction energy loss
- 3: Efficient environmental control
- 4: Efficient conversion, heat recovery, storage and re-use
- 5: Replace fossil fuel by renewable sources
- 6: Design of energy producing greenhouses

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1. Maximal use of solar energy/ natural light

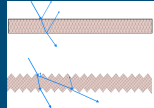
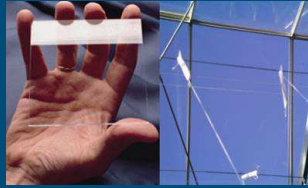
Maximal natural light: minimal construction parts and optimal transmission of the materials

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1. Maximal use of solar energy/ natural light

Covering materials:

- Anti reflex coating: +6%
- Shape of the material
 - V structure: material
 - Micro V: surface
 - Principle: multiple reflection increases light transmission



1. Maximal use of solar energy/ natural light

- Energy efficient: high light transmission (maximum use of natural light) combined with low IR transmission

Material	thickness	Light transmission	IR transmission
"standard" glas	4 mm	82%	0
hard glas	4 mm	82%	0
Anti Reflection glas	4 mm	ca. 89%	0
PE film	200 µm	ca. 81%	40-60%
EVA film	180 µm	ca. 82%	20-40%
ETFE membrane	100 µm	88%	15-20%
Poly Carbonate (2 layer)	12 mm	61%	0
PMMA (2 layer)	16 mm	76%	0
Poly Carbonate ZigZag	25 mm	80%	0

2. Reduction of energy loss: thermal screens

Screens

- Theoretical energy reduction >30%, practice: 20-25%)
- Main effects: higher humidity and less light
- Energy efficiency: + ca 20%

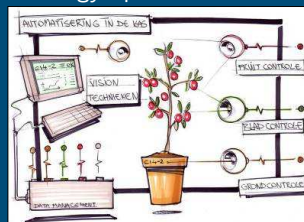


2. Reduction of energy loss

Greenhouse cover	relative energy use (equal environmental control)
Single (glass)	100 %
Single glass + screen	75 %
Double cover (fixed)	75 %
Triple	62 %
Double with low emission	53 %
Triple with low emission	49 %

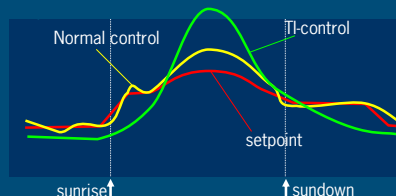
3. Energy Efficient operational control

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



3. Efficiënt environmental control: temperature

Temperature integration

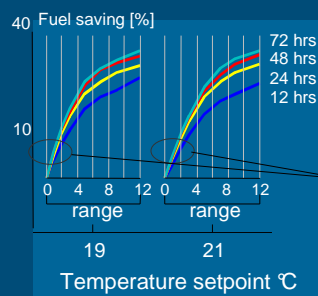


Principle: crop production related to average temperature between given limits

Energy saving: lower temperature during heating
higher temperature during sunlight: In practice: 5-8%

3. Efficiënt environmental control: temperature

Temperature integration



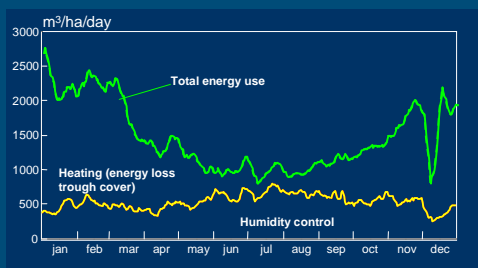
Effects of ranges and integration time at average temperatures of 19 and 21 °C

Ranges in practice



3. Efficiënt environmental control: humidity

Increasing the humidity setpoint +5%: energy -6%



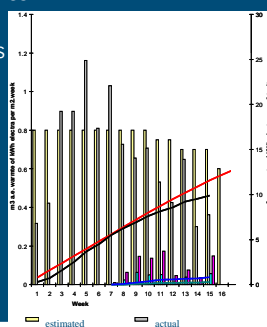
3 Energy efficiënt environmental control:

integrated approach tomato

Target: 50 kg tomato with 25 m³ gas

Basic equipment: optimal insulation (triple cover / 2 screens)

- 1 °C lower heating temperature, increased ventilation setpoint
- Active cooling
- 1st screen closed until 250 W/m²
- 2nd screen closed when $T_{\text{outside}} < 8^{\circ}\text{C}$
- Humidity setpoint ventilation > 85%



4. Efficient conversion, heat recovery, storage and re-use

The diagram illustrates a geothermal energy system. On the left, a 'Co generation' unit is shown. In the center, a 'Heat pump and Combined Heat Power' unit is depicted. On the right, 'Efficient water/air heat exchangers: heating and cooling' are shown. Below these, a cross-section of an 'Aquifer' is shown with temperatures of 9°C and 10°C. A circular inset shows a detailed view of the heat exchanger components.

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5. Replace fossil fuel by sustainable sources

- Options:
 - Biomass
 - Geothermal
 - Wind
 - Solar-energy
- Geothermal.
 - High sustainability
 - Application at area's >10 ha
 - Economic feasible at gasprice > €0.25 per m³ (=S_{can} 0.012/MJ)

The images show a field of yellow flowers (biomass), a bright sun (solar), a wind turbine (wind), and a cross-section of a geothermal well with a 90°C temperature (geothermal).

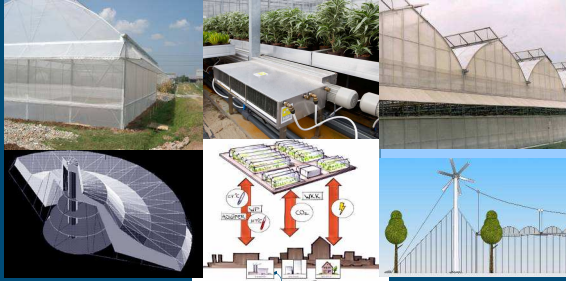
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Potential area's: geothermal energy and greenhouses

The left map shows the Netherlands with various colored regions indicating potential for geothermal energy. The right map shows the Netherlands with red dots indicating potential areas for greenhouses.

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6: Design of energy producing greenhouses



Trend in energy efficient greenhouses: (semi) closed / completely controlled

Advantages:

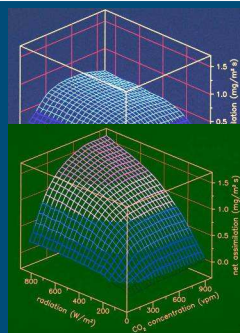
- Independent control of environmental conditions
- Cooling and dehumidification
- Higher CO₂ concentration and related production increase (up to 10-20%)
- Energy saving (+30%)

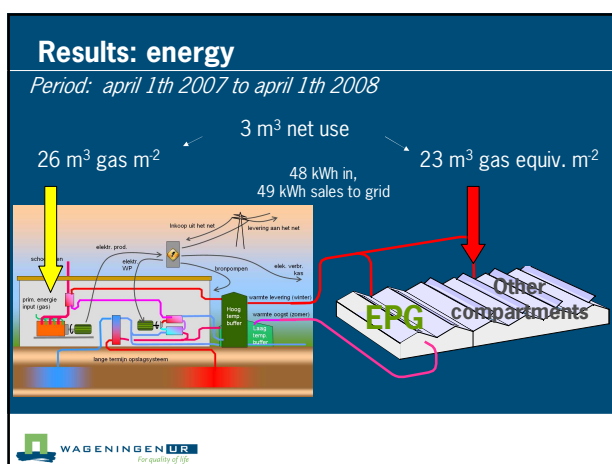
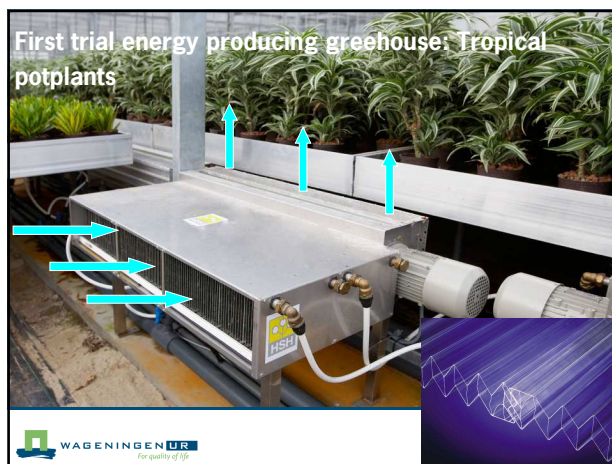
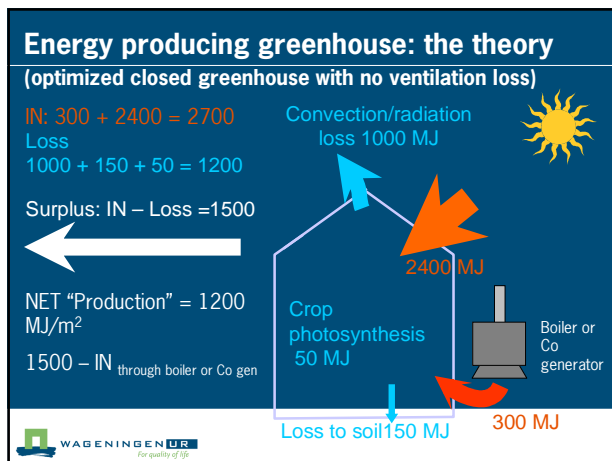


Completely controlled / energy efficient greenhouses

Environmental changes

- Traditional:
 - High radiation = high ventilation = low CO₂, low humidity and high temperature
- Controlled environment:
 - High radiation + high CO₂, low temperature and high humidity
 - Temperature distribution changes
 - Higher air velocity inside



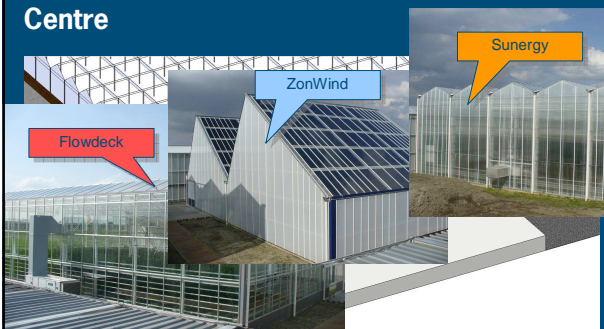


Overall results “Energy producing greenhouse”

- Energy:
 - Low energy use ($3 \text{ m}^3/\text{m}^2$)
 - Step ahead
- Crop production:
 - Equal or better quality
 - Estimated production increase: 8%
- Economic feasibility:
 - For application in commercial practice higher production increase and cost reduction needed
- Application results:
 - Higher light and humidity levels in traditional greenhouses (= less energy, higher production)
 - More focus on crop response

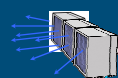
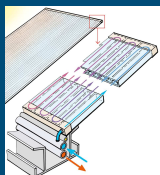


New designs: Innovation and Demonstration Centre

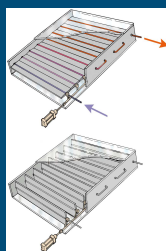


The principles: harvesting heat surplus

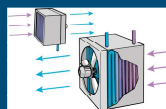
Flowdeck



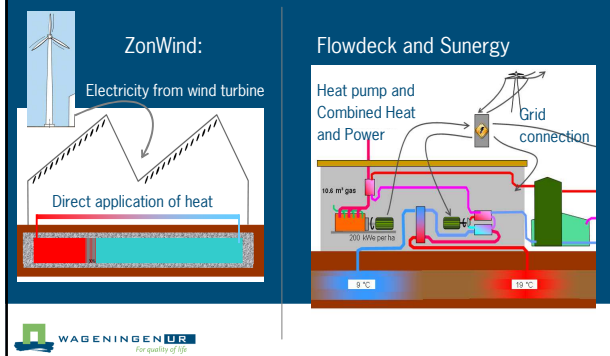
ZonWind



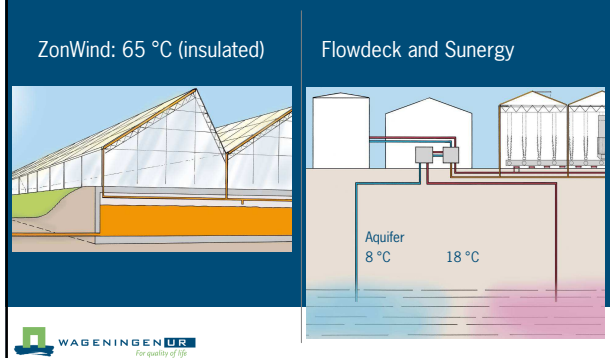
Sunergy



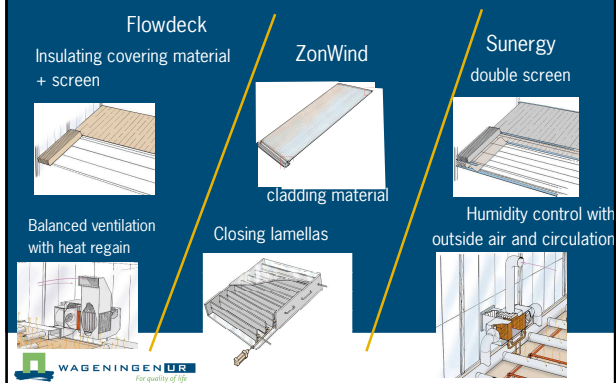
The principles: heating

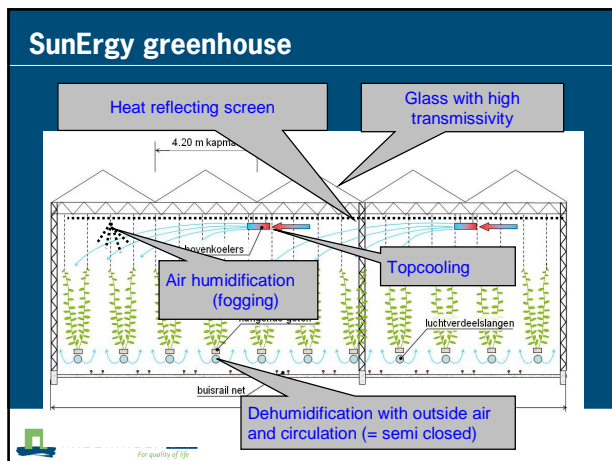


The principles: heat storage

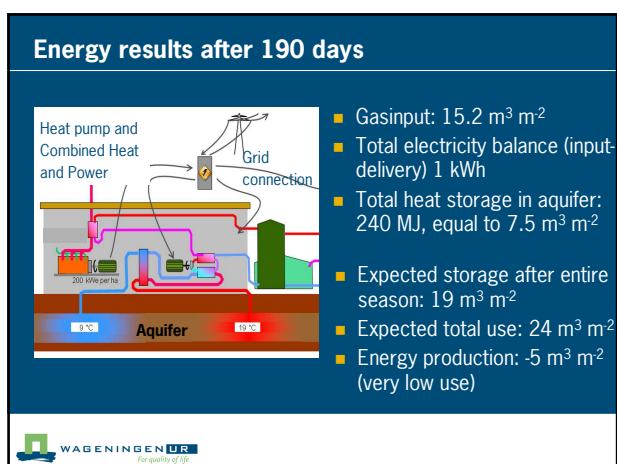


The principles: reducing heat loss



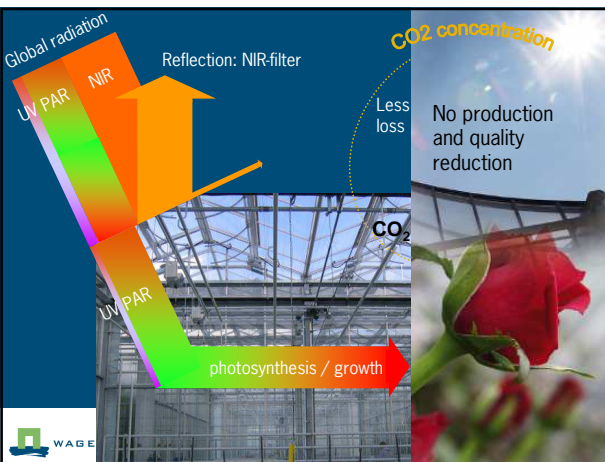






Latest developments

- Electricity producing greenhouse: NIR reflecting greenhouse cover:
 - Better summer conditions
 - Possibilities for electricity generation if combined with photo voltaic cells (Electricity production: 16 kWh/m² per year and) thermal 54 kWh/m²)



Thank you for your attention

Most of the projects shown are financed by:
the product board of Horticulture in the Netherlands
and
the Ministry of Agriculture, Nature and Food Quality

