Energy and climate in Dutch greenhouses

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Silke Hemming
Wageningen UR Greenhouse Horticulture, NL
silke.hemming@wur.nl

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For quality of life

Productschap Tuinbouw
Voor een bloeiende zaak

Ministerie van Landbouw, Natuur en Voedselkwaliteit

Climate controlled greenhouses

In current greenhouse horticulture:

- Market-oriented production
  - High production levels
  - High quality
  - Exact timeline of production
- → control of production environment needed
- → more conditioned greenhouses

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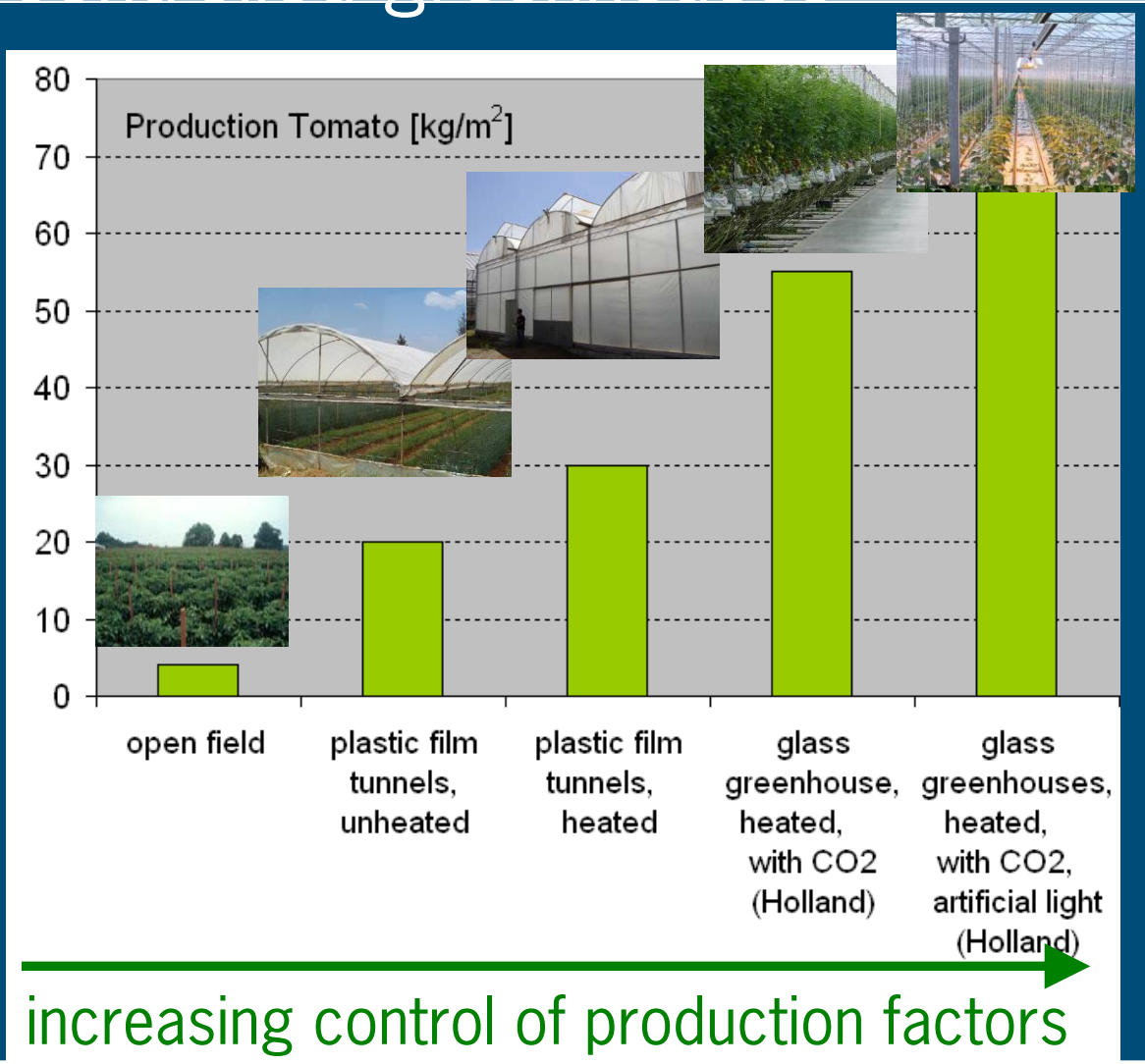
Climate controlled greenhouses



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Energy efficient greenhouses

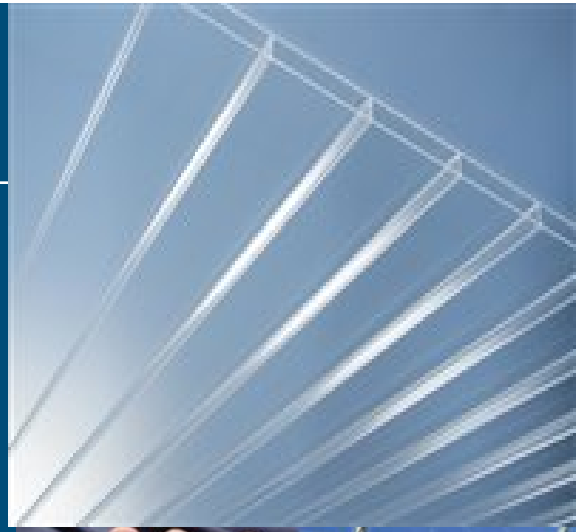
- Energy: 20-30% of production costs
- Targets greenhouse sector in the Netherlands 2020:
  - -48% CO_2 emission compared to 1990
  - new build greenhouses operate (almost) without fossil fuel
- → reduction of (fossil) energy consumption

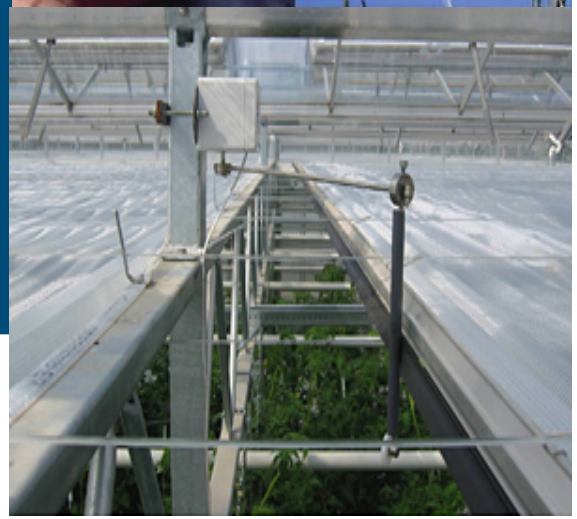


Energy efficient greenhouses

Steps:

- Maximum use of solar energy
  - High light transmission of greenhouse (construction, covering, coatings, reduce screen use…)
- 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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Energy efficient greenhouses

Steps:

- Maximum use of solar energy
- Reduction of energy loss
  - Winter: minimize energy loss (double AR glass, low-e coating, thermal screens…)
  - Summer: efficient cooling (natural ventilation, fogging…)
- 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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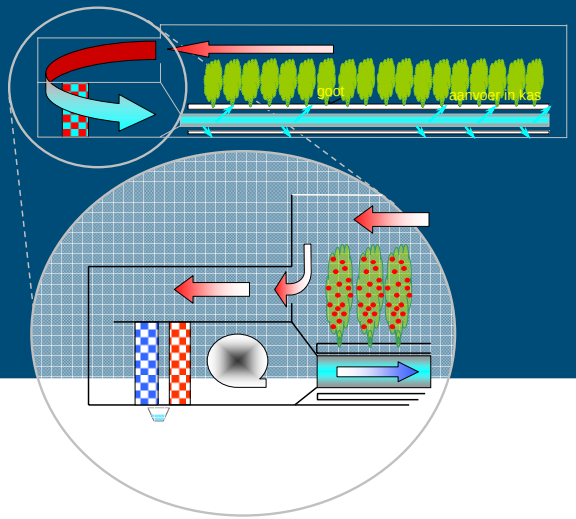
Energy efficient greenhouses

Steps:

- Maximum use of solar energy
- Reduction of energy use
- Efficient conversion of energy, heat storage and re-use
  - Co-generation, efficient conversion of solar energy, heat exchanger, heat storage and re-use
- Efficient energy use:
  unit product per unit energy
- Replace fossil by renewable energy



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Energy efficient greenhouses

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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Energy efficient greenhouses

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
- Replace fossil by renewable energy
  - Biofuels, biogas, wood, solar cells, geothermal, wind….

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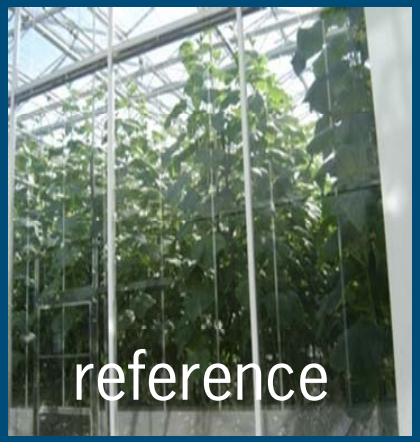
Maximum use of sun light

Diffuse light



Spring crop 2008 Kg/m^2	+6.5%	+9.2%
Autumn crop 2008 Kg/m^2	+8.8%	+9.7%
	No light loss	3% less light

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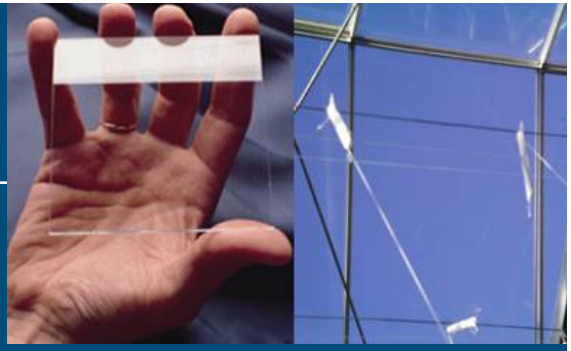
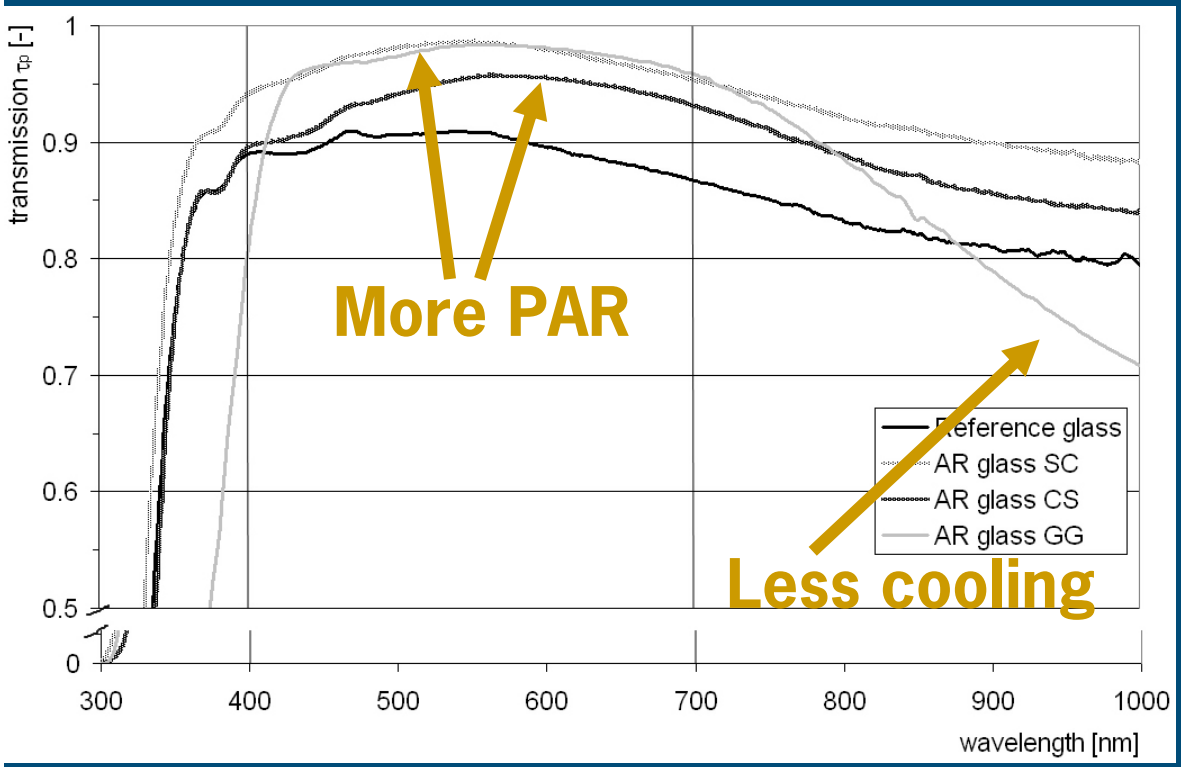
Hemming et al.

Maximum use of sun light

Modern coatings





- More PAR by AR coating → higher production
- Spectrum changed UV and/of NIR
- Cooling less under GG but energy consumption higher
- Energy saving under double materials without light loss

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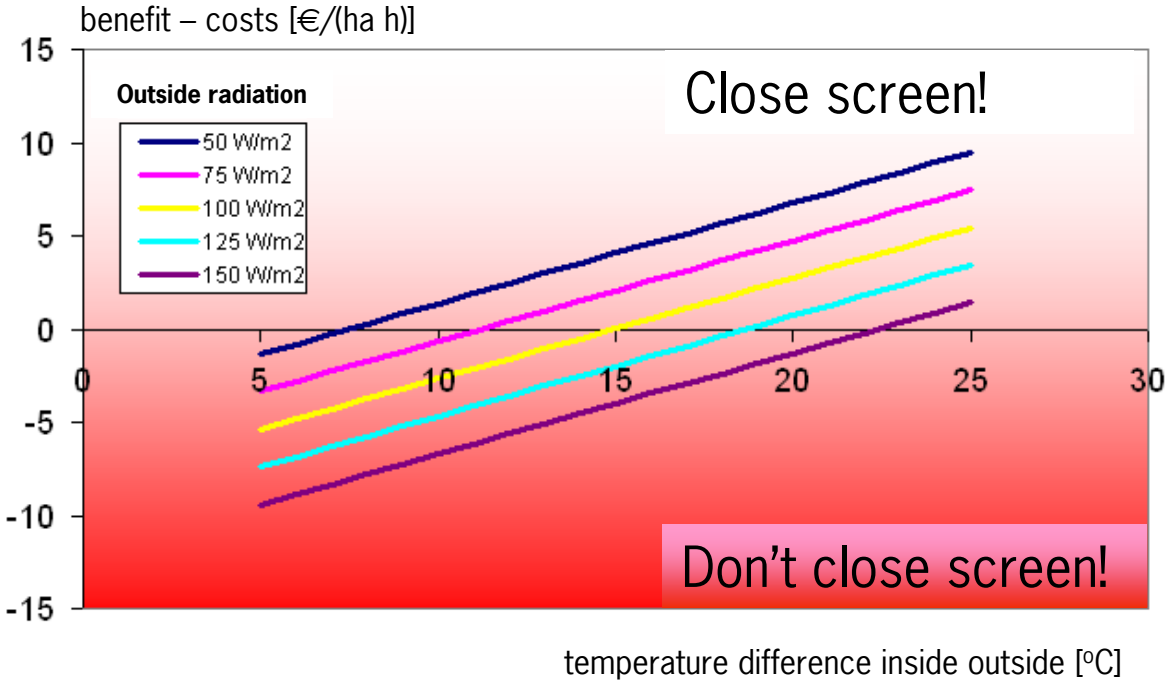
Hemming et al.

Reduction of energy loss

- Screens
  - Theoretical energy reduction >30%, practice: 20-25%
  - Main effects: higher humidity and less light
  - → screening strategies
  - → new materials

Reduction of energy loss

kastransmissie	75	%
Productprijs	0.50	€/kg
gasprijs	0.25	€/m³ (7.9 €/GJ)
schermtransmissie	80	%
kwaarde verlaging	1.9	W/(m² K)
lichtconversiefactor	22	gr/MJ



Reduction of energy loss

- Venlow Energy Greenhouse
- Double glass
- Modern coatings: AR, low-ε
- Extra low u-value, high energy saving potential
- Light transmission ~ single glass
- Together with new growing strategies 16-20m^3 gas for tomato production?

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maurice KASSENBOUW BV

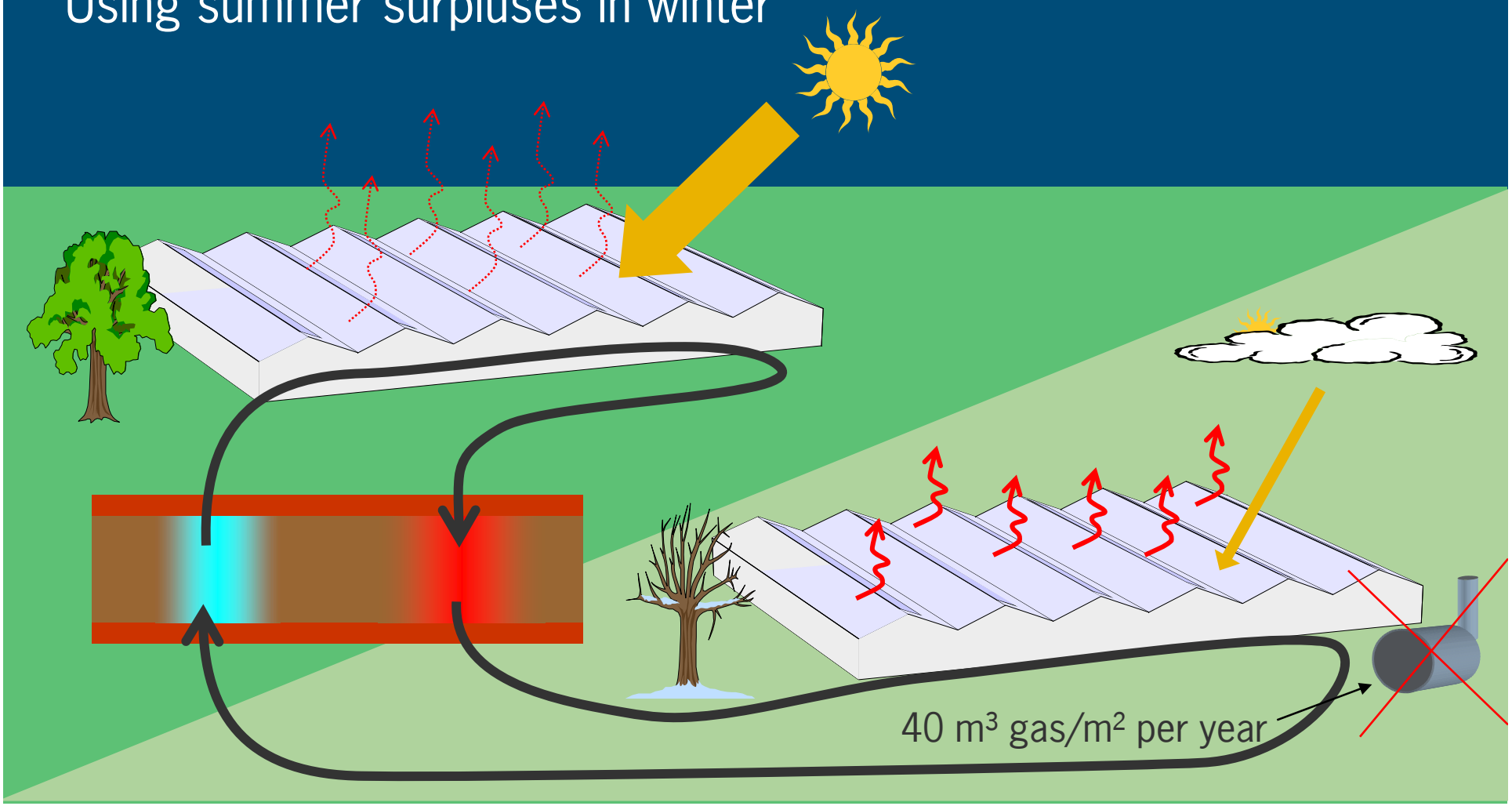
BOAL SYSTEMEN

Climeco Engineering B.V. solar | glass

Scheuten

Efficient energy conversion, storage and re-use

Using summer surpluses in winter



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De Zwart et al.

Efficient energy conversion, storage and re-use

- Fully closed greenhouse has serious heat excess → only a fraction of the greenhouse can be closed
- Heat must be harvested at low temperatures → large heat exchanging surfaces or considerable electricity consumption for driving ventilators
- High value energy (electricity) instead of low value energy (gas)
- Heat must be stored for half a year → small ΔT results in large storage volumes (around 30 m^3 of water per m^2 greenhouse) → aquifer needed
- Temperature will drop during storage → heat pump needed

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De Zwart et al.

Semi-closed greenhouses

- Different devices

- Central or de-central heat exchangers
- Cooling from below or above
- With or without additional ventilation with outside air
- Forced cooling or evaporative cooling

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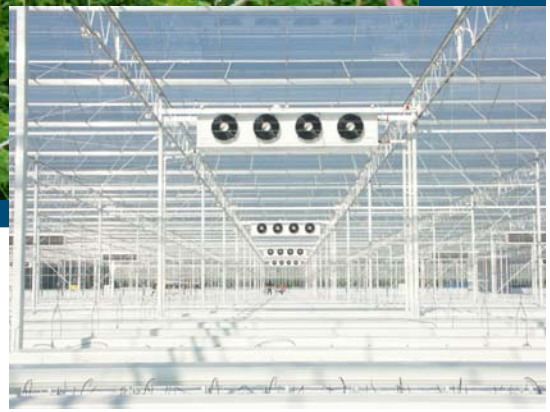
Semi-closed greenhouses



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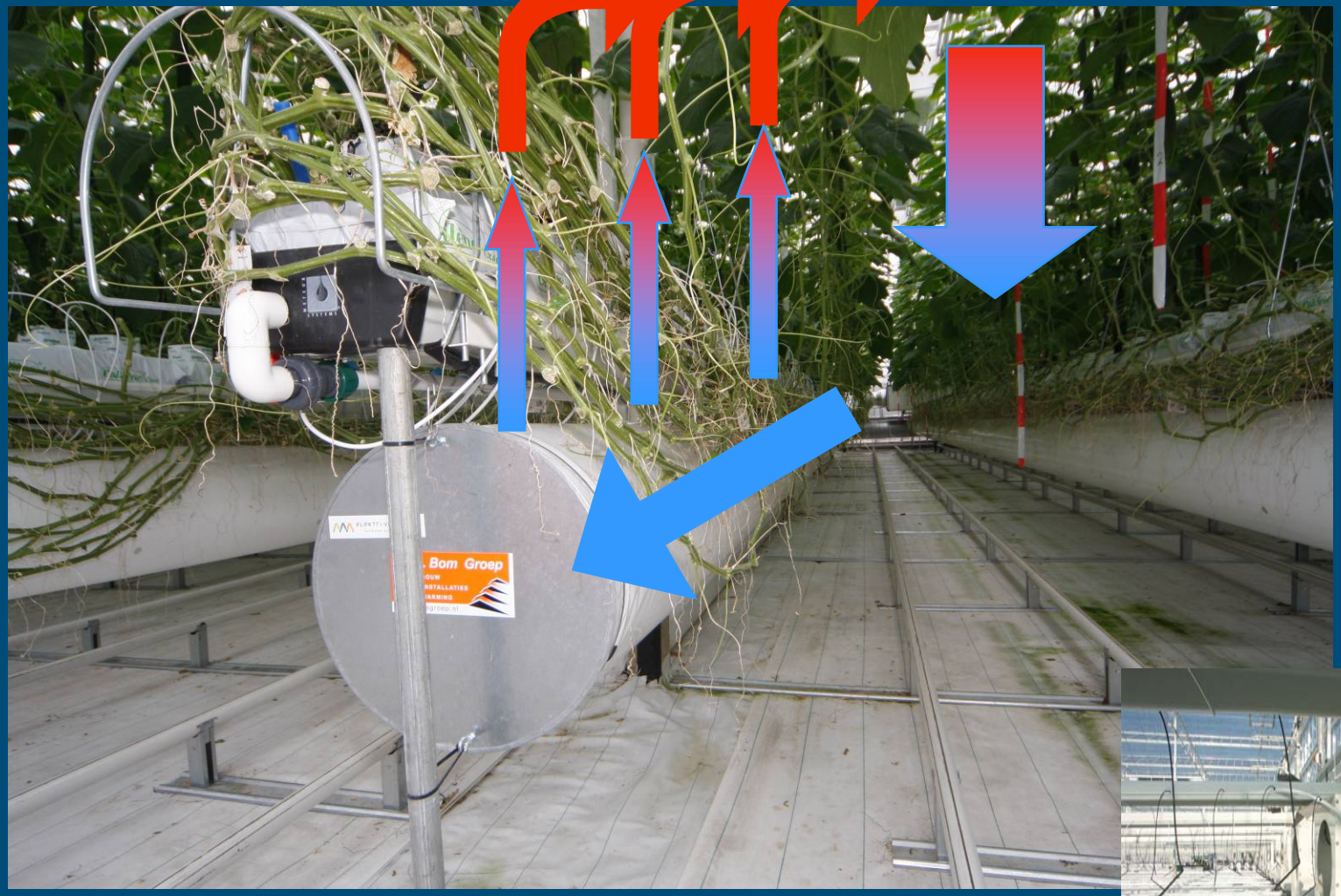
Semi-closed greenhouses



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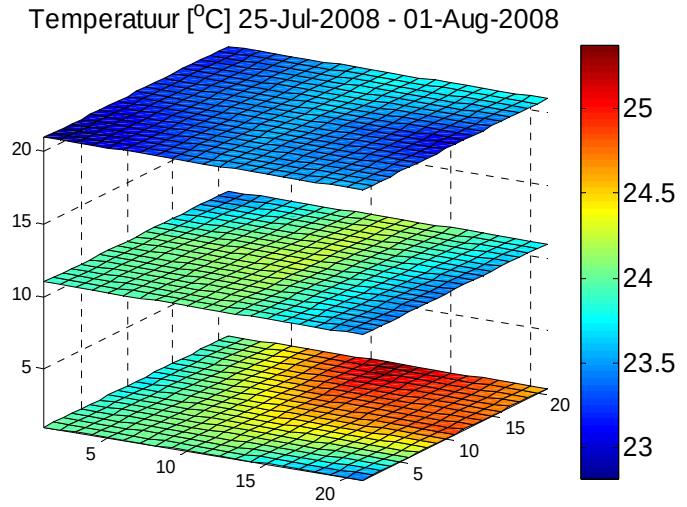
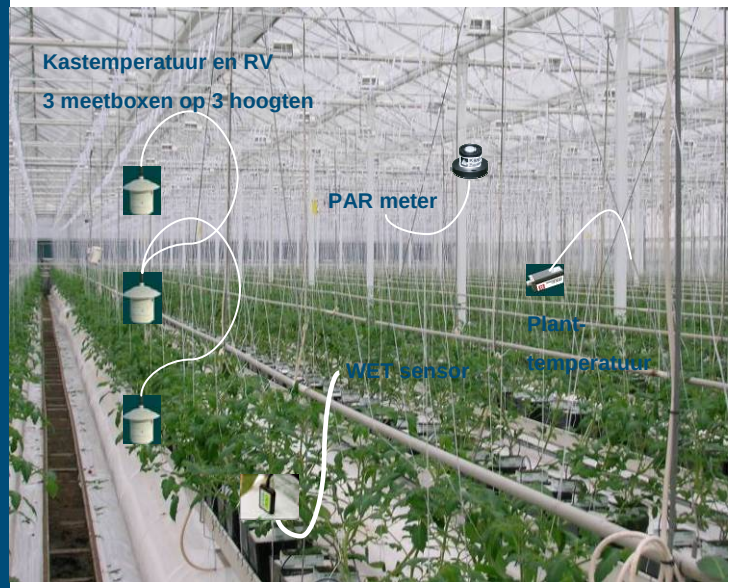
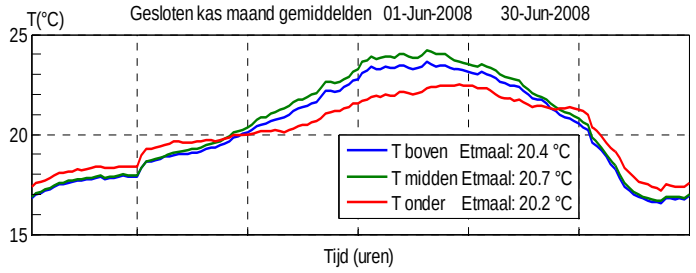
Semi-closed greenhouses

- Climatic aspects

- Which device is the best?
- Which climate is realized?
  - Temperature
  - Humidity
  - CO_2







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Campen et al.

Semi-closed greenhouses

- Cooling from below creates a vertical gradient in temperature and humidity compared to natural ventilated greenhouse
  - If differences are too high
    → lower fruit temperatures will result
    → ripening time will increase
    → increase of fruit load
    → overall result: decrease of production
- Climate is inhomogeneous (horizontal and vertical)
- Air ducts increase energy consumption
- Cooling from above with decentralized units is possible if fans distribute the air
- Cost-benefit is depending on crop and installation

Efficient energy use

- Crop aspects
- Higher energy efficiency by
  - Higher CO_2 levels
  - Temperature integration
  - Higher humidity levels
  - (Higher light levels)

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Efficient energy use – CO_2

- Increased CO_2 concentrations → higher yield

	Open greenhouse	Semi-closed (150 W/m^2)	Semi-closed (350 W/m^2)	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

Supply capacity: 230 kg CO_2 ha^{-2} h^{-1}

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Quian, 2008

Efficient energy use - Temperature

- Temperature = Main factor determining energy use (75-90%)
- Reduction of temperature set point by 2 °C
- Temperature integration TI (24 h, 4 °C)

	Energy use ($m^3\ m^{-2}\ y^{-1}$)	Production ($kg\ m^{-2}\ y^{-1}$)
Reference	45.3	58.9
Lower T	38.3 (- 16%)	57.0 (- 3%)
TI	43.3 (- 4%)	58.5 (- 1%)

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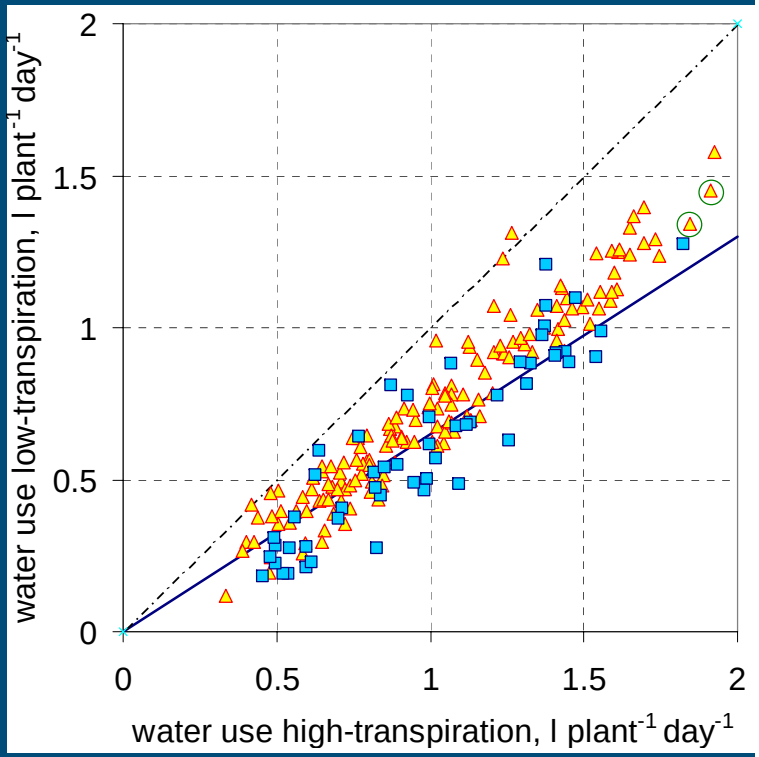
→ Save heating energy

Elings et al., 2005

Efficient energy use - humidity

- Air humidity = 10 - 25% of energy use

- Increase humidity set point
- Decrease transpiration (here: 65% of reference)
  - Ventilation
  - Heating
  - Humidification
- 4 tomato crops
- Less water uptake →
- No effect on production (!)
- X% reduction in energy use



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Li & Stanghellini, 2004

Efficient energy use - new growing concept tomato

60 kg tomato with 26 m^3 gas

- high insulation (single glass + 2 screens)
  - transparent screen closed until 250 W/m^2
  - energy screen closed when $T_{outside} < 8^oC$
- 1^oC lower heating temperature
- Increased ventilation set point → more CO_2
- Active cooling
- Humidity set point ventilation > VPD 1.5g/m^3, air circulation
- OCAP CO_2

Oktober 2009

Het Nieuwe Telen

In 7 stappen naar ruim 50% energiebesparing

Bestaande glastuinbouwbedrijven kunnen profiteren van nieuwe inzichten, die het programma Kas als Energiebron heeft opgeleverd. In proeven op semipraktijkschaal blijkt het mogelijk om met deze kennis en zonder hoge investeringen aanzienlijk te besparen op het energieverbruik. Bij Het Nieuwe Telen staan de plant en de teelttechniek centraal.

De afgelopen jaren is er veel bijgeleerd over de omstandigheden waaronder een gewas zich lekker voelt in de kas. Bovendien hebben verschillende projecten nieuw inzicht opgeleverd over hoe temperatuur- en vochtverdeling in kassen beter te regelen is. Uit proeven op het Improvement Centre blijkt dat met minder energie dezelfde resultaten kunnen worden gehaald.

Stapsgewijs invoeren

Deze nieuwe kennis kan op de meeste bedrijven worden toegepast, ook op bestaande bedrijven. Afhankelijk van de bedrijfssituatie kan een teler één of meer van de volgende maatregelen stapsgewijs invoeren. De eerste twee stappen leveren het meeste op tegen lage investeringskosten.

STAP 1 Niet langer droogstoken met de minimumbuis en de ramen op een kier, maar vocht afvoeren door gecontroleerd toedienen van (droge) buitenlucht. Dit is goed voor zo'n 15% energiebesparing.

STAP 2 Intensief isoleren met een energiescherm. Dat wil zeggen meer uren schermen, meerdere schermen toepassen en werken met beter isolerende schermen. Dit levert nog eens 15% besparing op.

STAP 3 Telen met de natuur mee: maak gebruik van temperatuurintegratie. Pas plant- en oogstdata aan en profiteer optimaal van zonlicht en zonnewarmte. Dit kan 5% besparing opleveren op uw energierekening.

STAP 4 Zorgen voor gecontroleerde luchtbeweging. Dit verbetert de horizontale temperatuur- en vochtverdeling en dat verkleint de kans op schimmelaantasting.

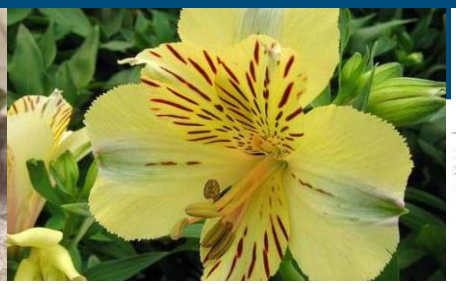
STAP 5 Door de lucht te bevochtigen bij warm en zonnig weer kunnen de ramen langer dicht blijven. De plant kan dan beter CO_2 opnemen. Het resultaat is meerproductie.

STAP 6 Toepassen van actieve koeling, waardoor overdag de ramen langer dicht kunnen blijven, zodat er meer CO_2 beschikbaar is voor de plant, of 's nachts om de etmaaltemperatuur te verlagen met positieve effecten op de gewasontwikkeling. Dit leidt tot meerproductie.

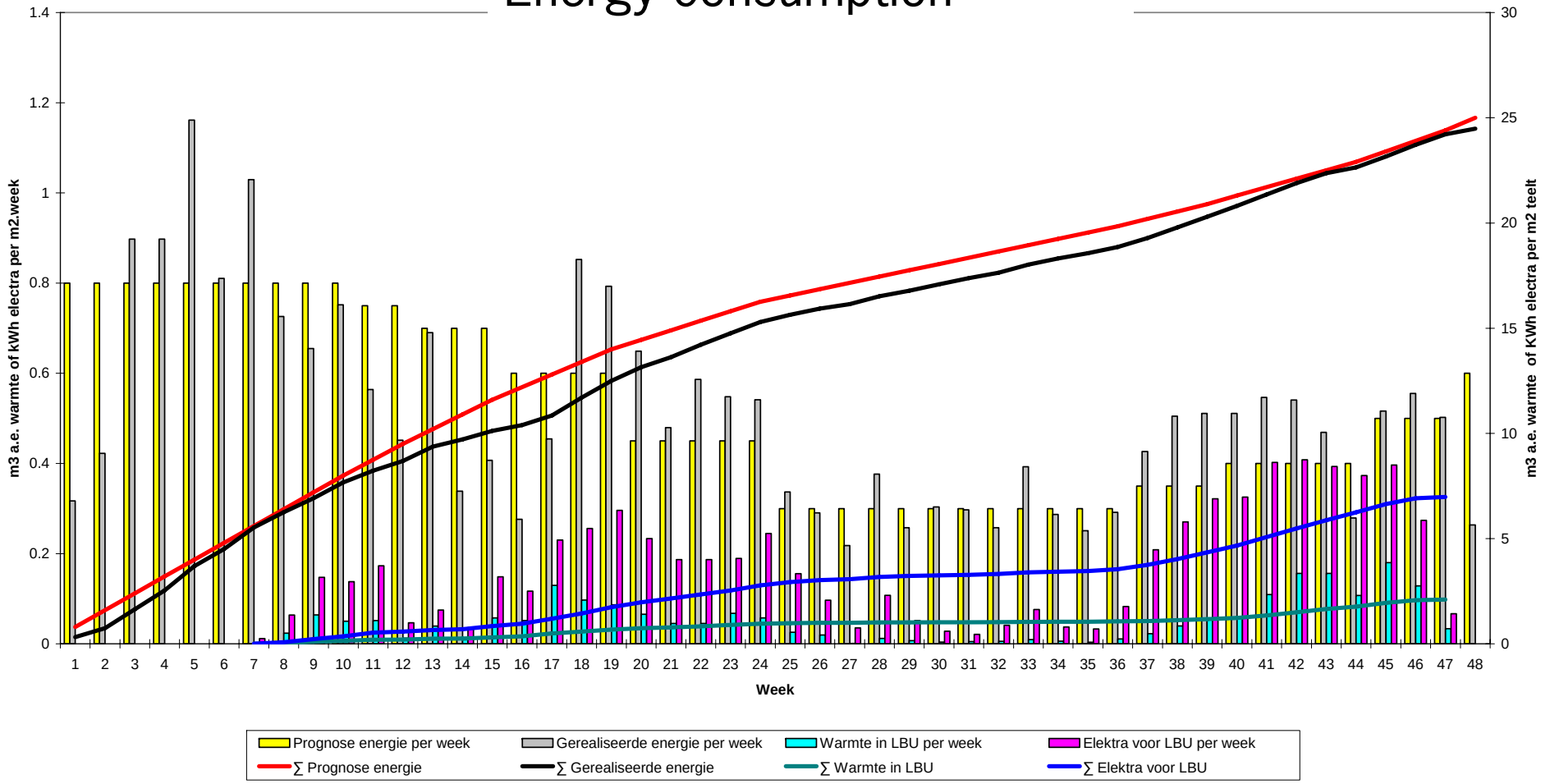
STAP 7 Voor teelten waar actief gekoeld wordt, is een aquifer te overwegen. Warmte in de zomer kan zo worden opgeslagen voor gebruik met een warmtepomp in de winter. Dit levert nog eens 25% energiebesparing op.

De genoemde percentages zijn een indicatie van de hoeveelheid energie die kan worden bespaard door de betreffende maatregel. Met als referentie een intensieve onbelichte teelt met een warmtevraag van 40 m^3/m^2. Voor een specifieke bedrijfssituatie kunnen andere besparingen gelden. Deskundige adviseurs kunnen berekenen hoe de verschillende maatregelen zullen uitpakken.





Energy consumption

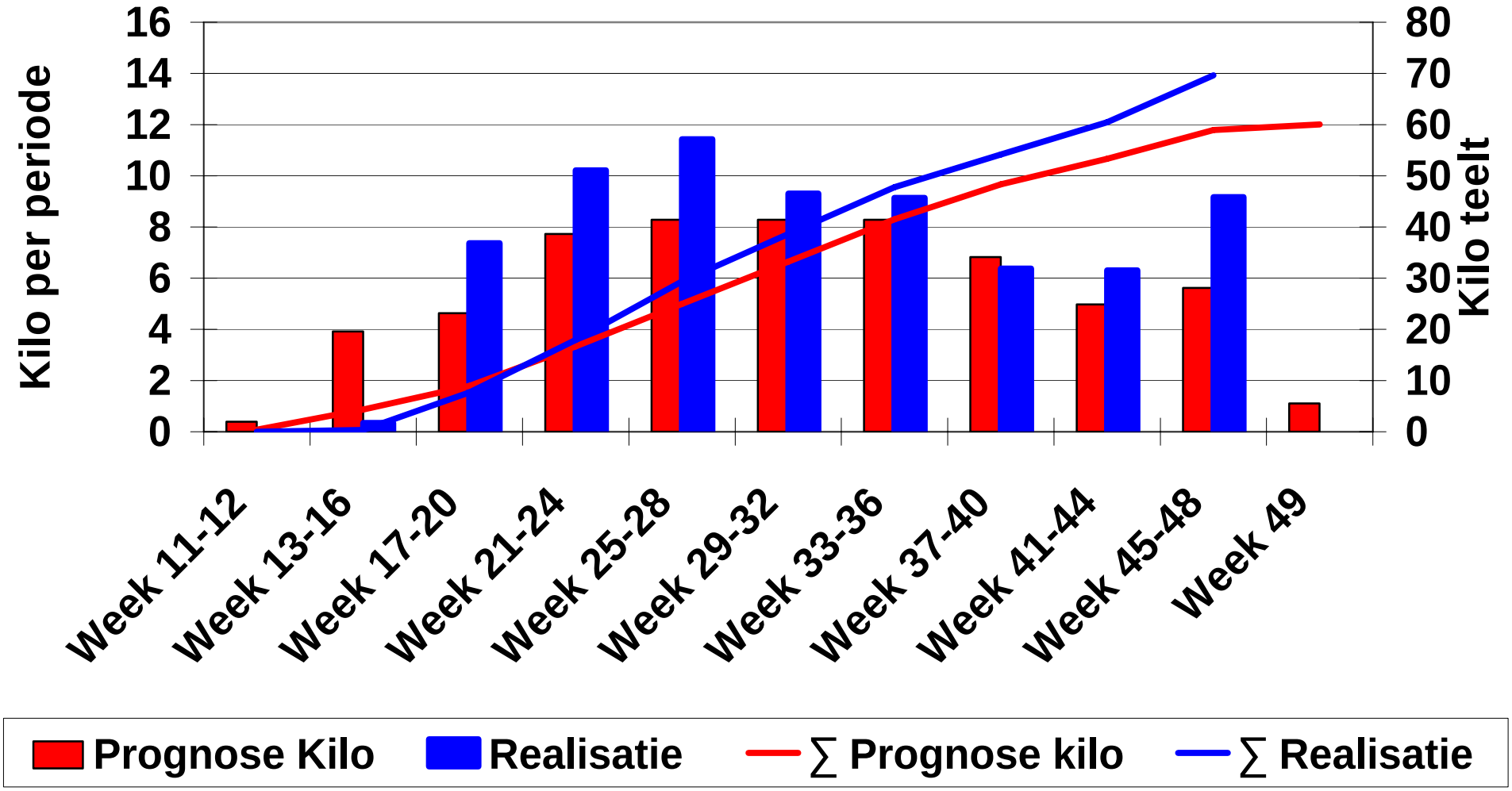


Project : **Het Nieuwe Telen**
Energie onder de knie.
Een richting gevend beeld realiseren.

Uitvoering door :

De Gelder et al., 2009

Production tomato



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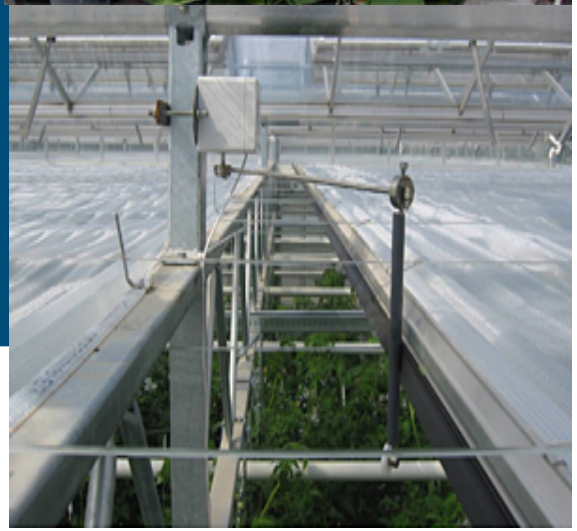
De Gelder et al., 2009

Examples of energy saving greenhouse systems



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Examples of greenhouse systems

- Innovation and Demo Centrum IDC
  - Sunergy Greenhouse (Bom Kassenbouw, Wageningen UR)
  - FlowDeck Greenhouse (Climeco Engineering, Maurice Kassenbouw, HAS Den Bosch)
  - SunWind Greenhouse (Thermotech, Gakon Kassenbouw)
- Ca. 500m^2 each greenhouse

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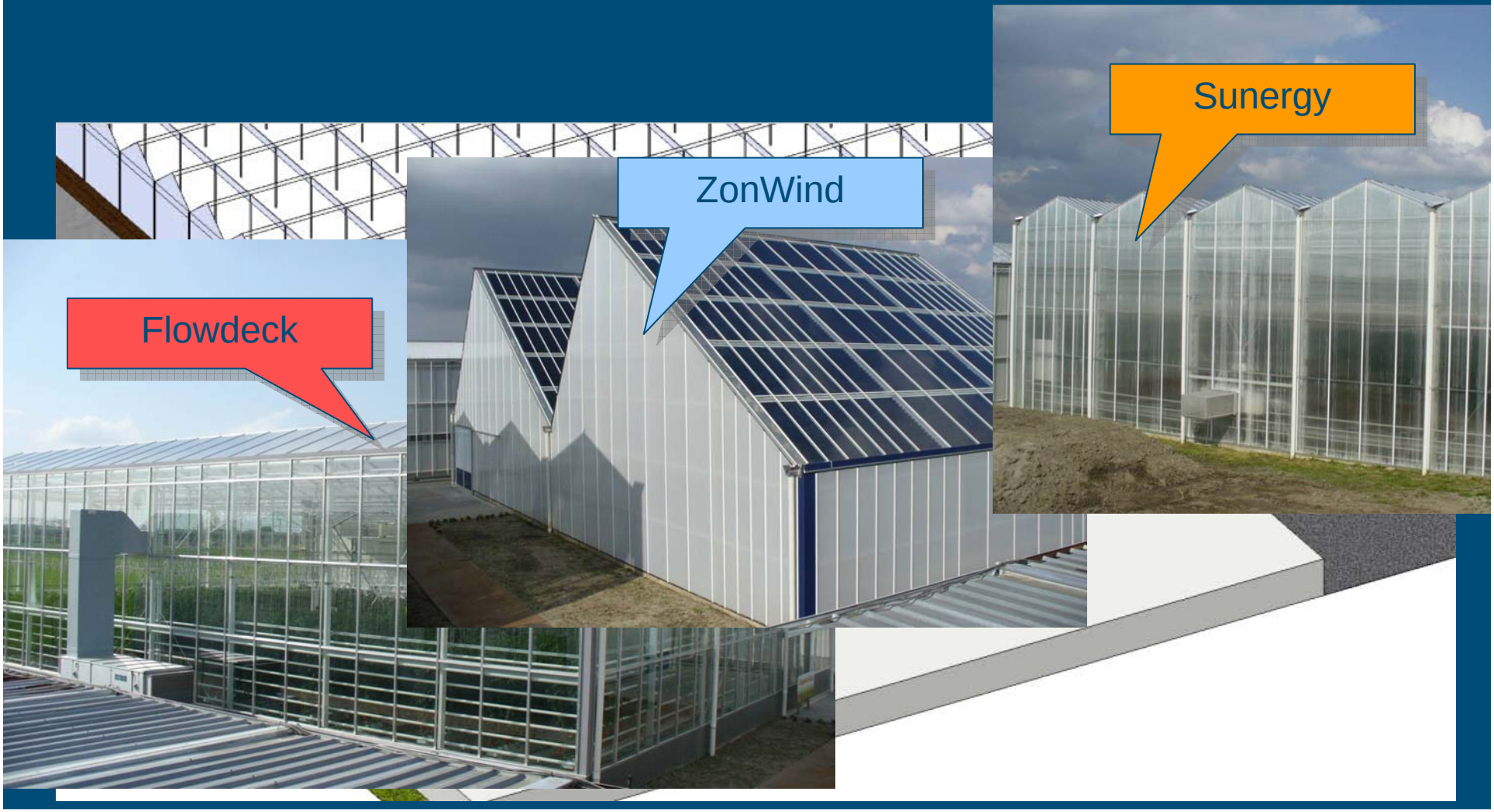
Innovation and Demonstration Centre IDC



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Kas als Energiebron

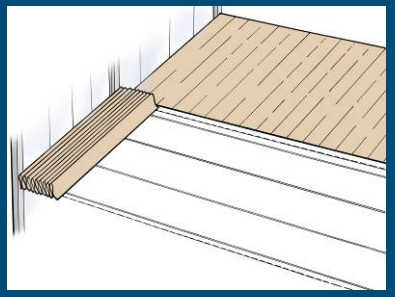
Productschap Tuinbouw
Voor een bloeiende zaak

Ministerie van Landbouw, Natuur en Voedselkwaliteit

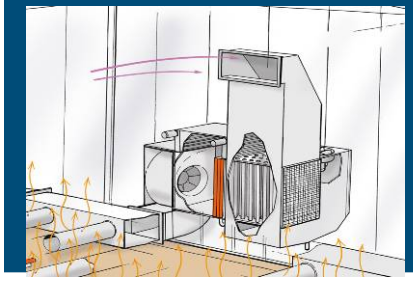
The principles: reducing heat loss

Flowdeck

Double layer PC + screen



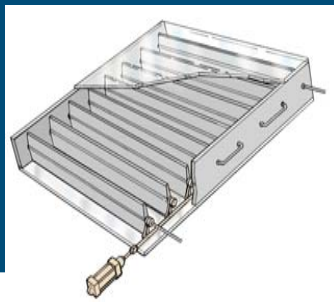
Balanced ventilation with heat regain



ZonWind

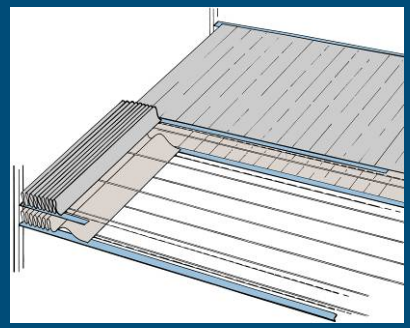
Double glass with lamellas inside

Closing lamellas

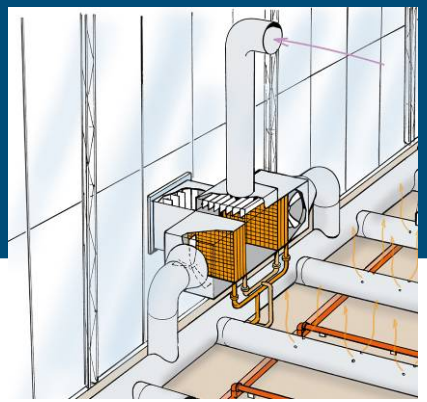


Sunergy

Double screen



Humidity control with outside air and circulation



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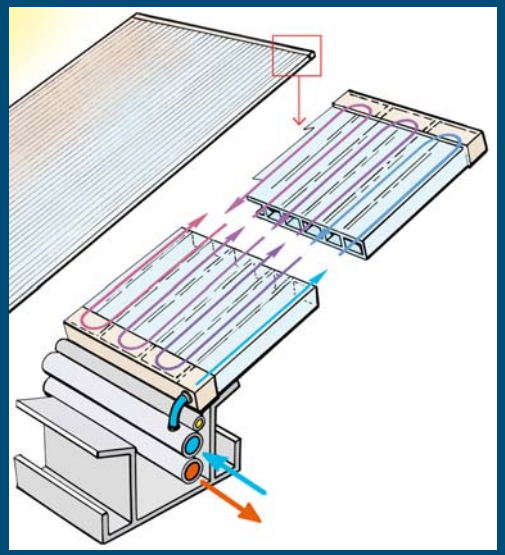
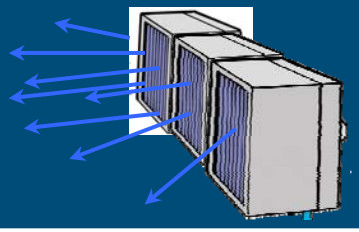
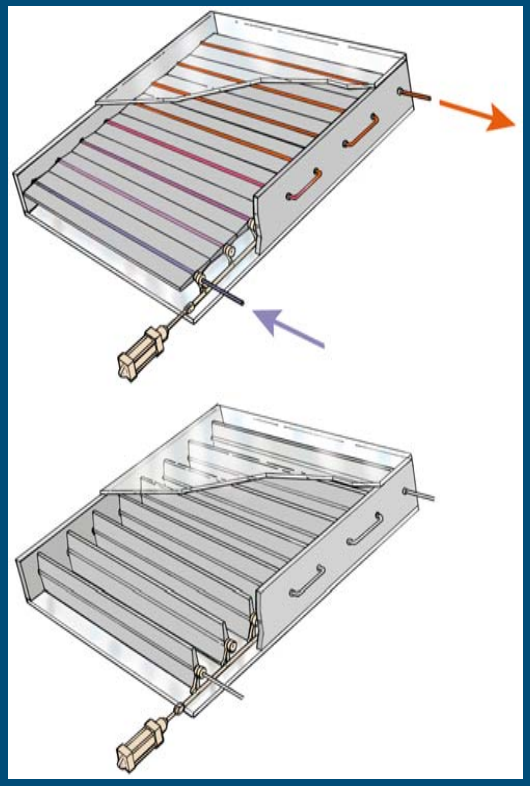
The principles: harvesting heat surplus

Flowdeck

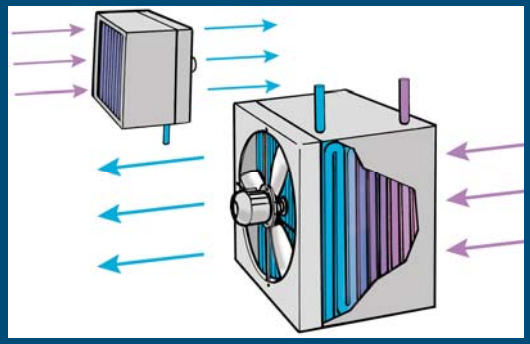




ZonWind



Sunergy



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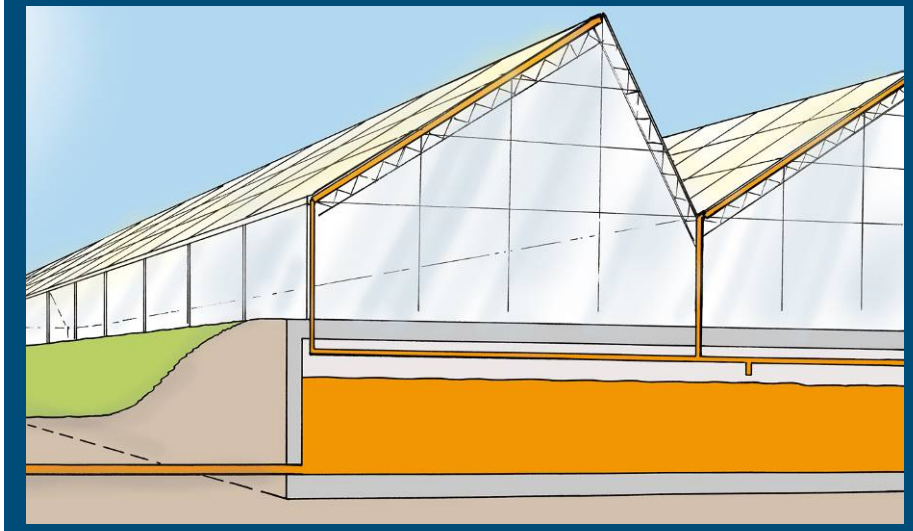
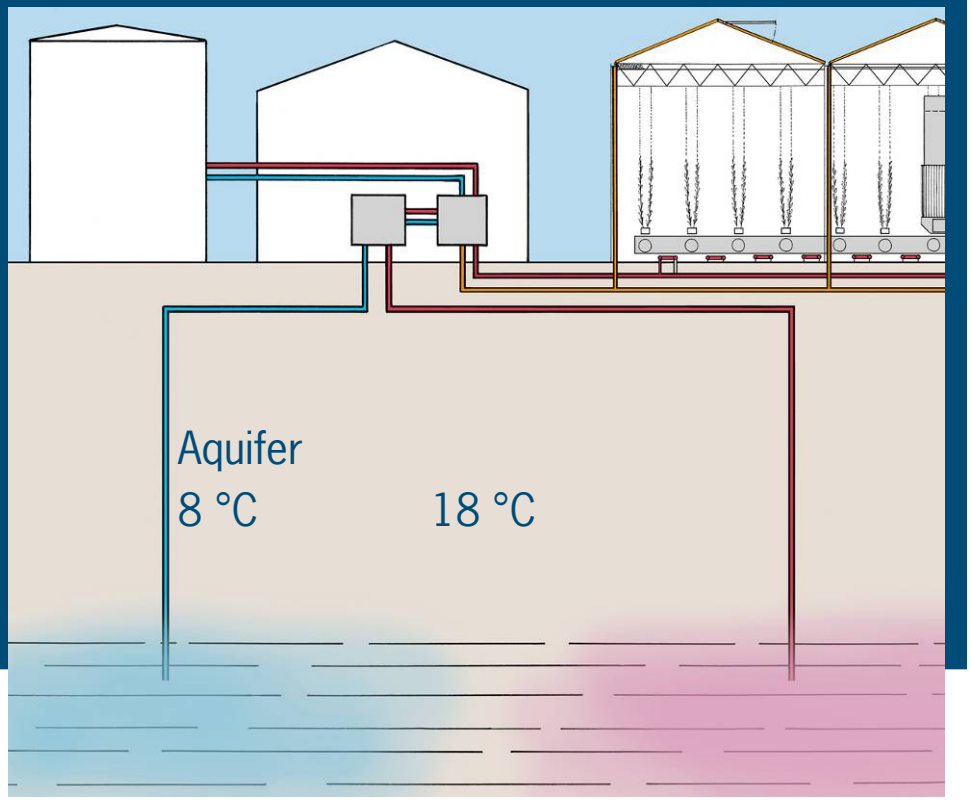
The principles: heat storage

ZonWind: 65 °C insulated tank under greenhouse



Flowdeck and Sunergy



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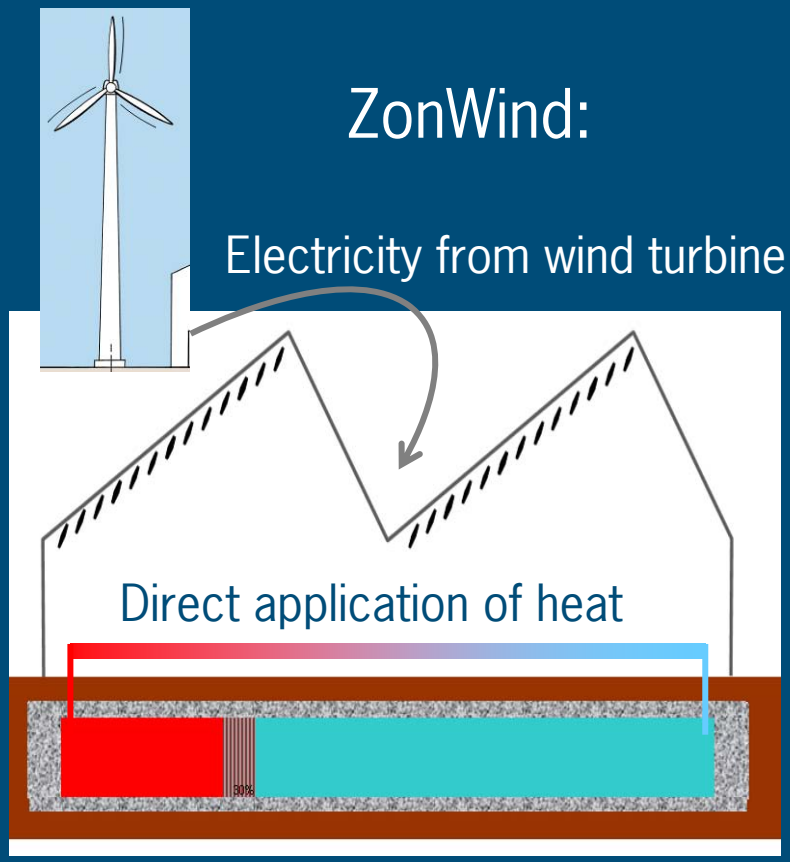
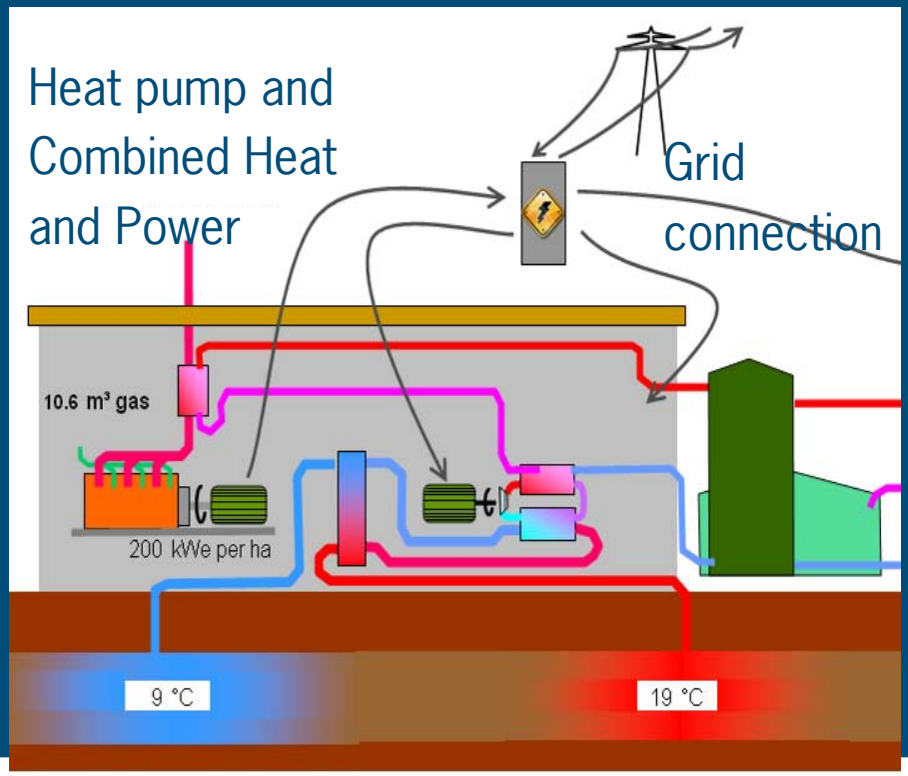
The principles: heating

ZonWind:



Flowdeck and Sunergy



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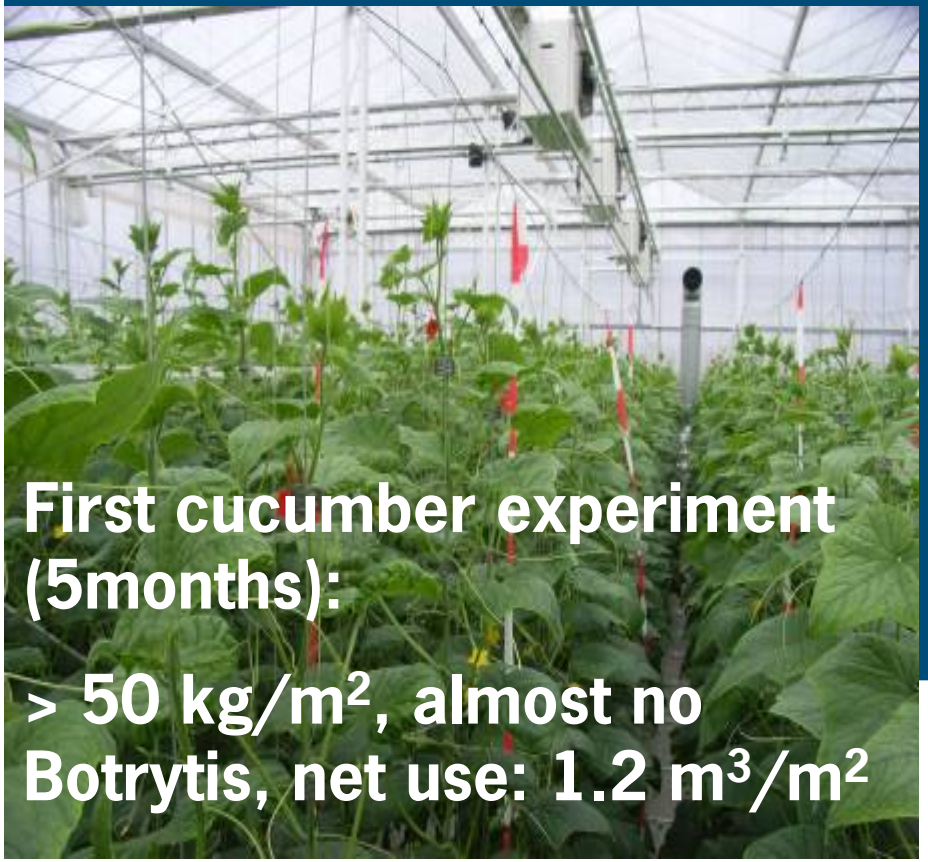
IDC - Sunergy



First cucumber experiment (5months):

> 50 kg/m^2, almost no Botrytis, net use: 1.2 m^3/m^2

Tomato experiment:

76.2 kg, planting 16 dec. 2008

Electricity producing greenhouse

- Separation of solar radiation PAR – NIR (selective film on roof)
- Focusing of the NIR radiation (roof shape and movable arm)
- Conversion of NIR into electrical energy (photo voltaic cells)
- Plant production & electricity generation (16-28 kWh/m^2 per year)

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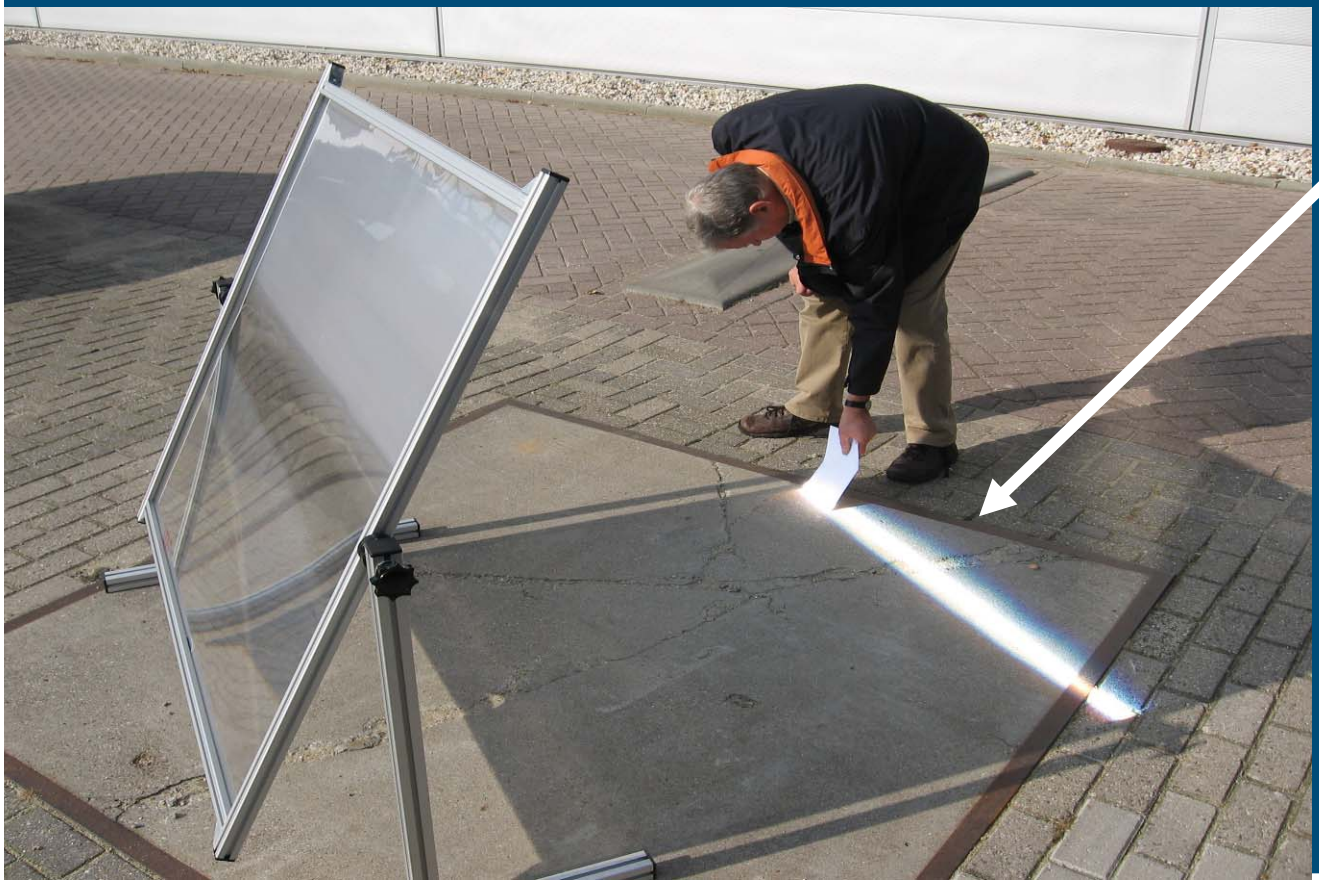
Sonneveld et al., 2008

Electricity producing greenhouse

Fresnel lens greenhouse



Concentration of direct light

→Photo voltaic cells produce electricity

→(50-100kWh/m^2 per year)

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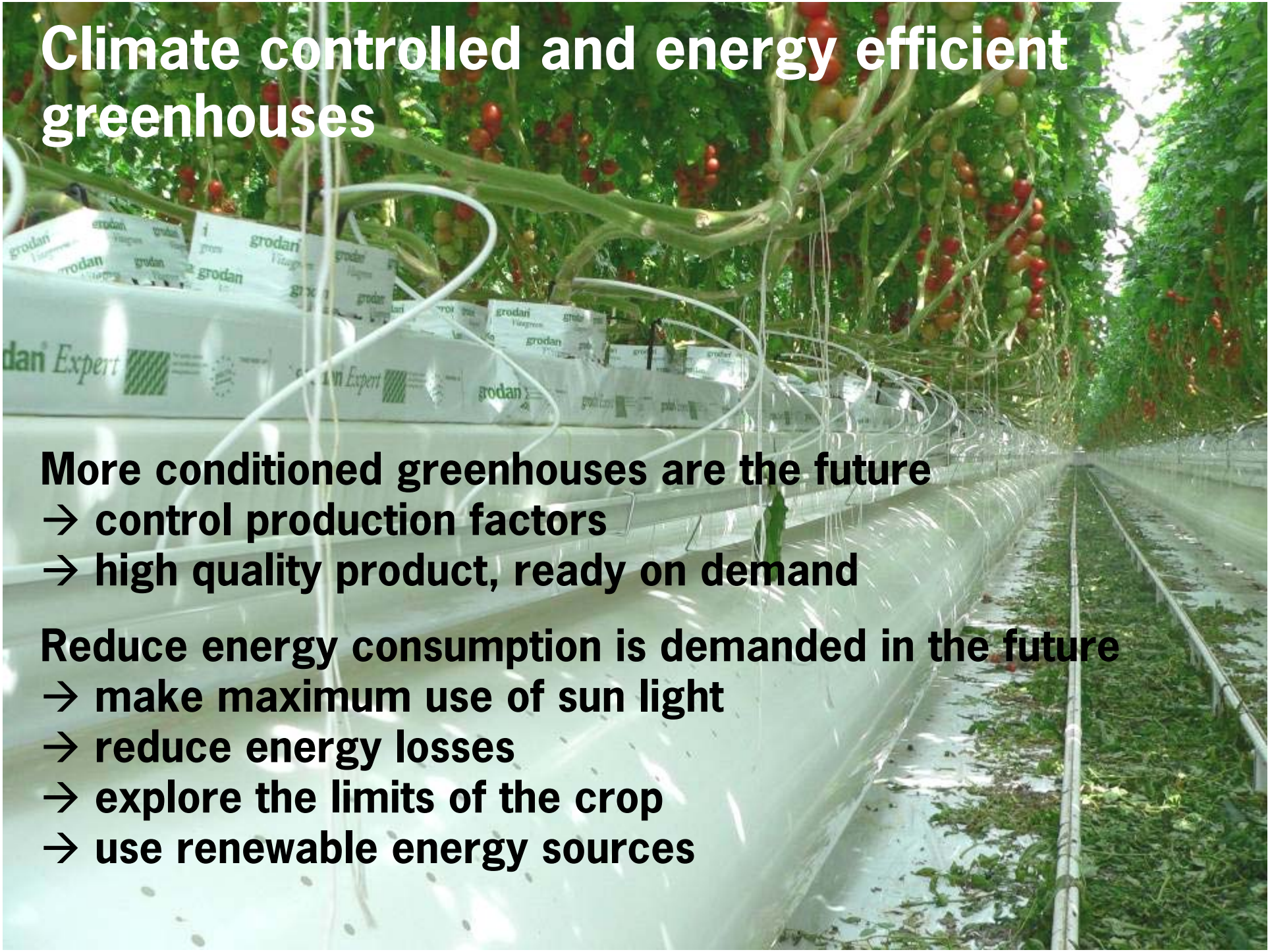
TECHNOKAS

Bode Project- en Ingenieursbureau

Climate controlled and energy efficient greenhouses



More conditioned greenhouses are the future
→ control production factors
→ high quality product, ready on demand

Reduce energy consumption is demanded in the future
→ make maximum use of sun light
→ reduce energy losses
→ explore the limits of the crop
→ use renewable energy sources

Wageningen UR

Innovation for a greener horticulture

Thanks to all my colleagues contributing to this research

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WAGENINGEN UR
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Productschap Tuinbouw
Voor een bloeiende zaak

Ministerie van Landbouw, Natuur en Voedselkwaliteit