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Sustainable greenhouse design

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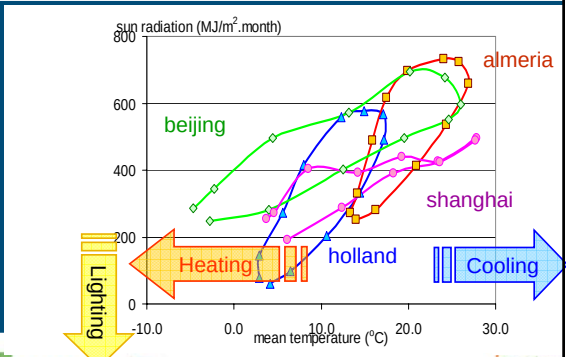
Trends in Horticulture

- Increase of production scale/ intensity
- Better control of environmental conditions
- Yearround crop production
- Reduction of energy and water use

Environmental conditions: different worldwide



Major challenge

- 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"

Step 1 Requirements and objectives

- Requirements*:
  - Market size and regional infrastructure
  - Local climate
  - Availability, type and costs of fuels and electric power
  - Availability and quality of water
  - Soil quality and topography
  - Availability and cost of land, zoning restrictions
  - Availability of capital
  - The availability and cost of labour and the level of education
  - The availability of materials, equipment and service level
  - Legislation in terms of food safety, residuals of chemicals, the use and emission of chemicals to soil, water and air

*Hanan, 1998 and Van Heurn and Van der Post, 2004

Step 1 Requirements and objectives

- Objectives:
  - Reduction of energy
  - Minimal water use
  - Better production and quality
  - .....

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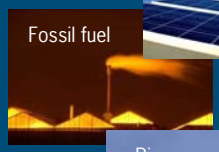
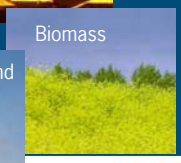
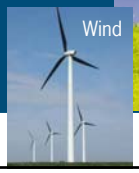
Step 2: Functions and working principles

- Region: Northern and Southern Europe
- Required functions:
  - Energy supply
  - …
  - …







Step 2: Functions and working principles

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  - Heating
  - …
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Step 2: Functions and working principles

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  - Dehumidification/cooling
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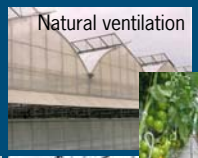

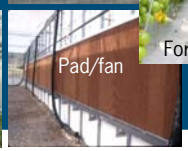

Step 2: Functions and working principles

- Region: Northern and Southern Europe
- Required functions:
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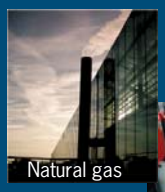
  - Heating
  - Dehumidification/cooling
  - CO_2 supply
  - …
  - …



Step 2: Functions and working principles

- Region: Northern and Southern Europe
- Required functions:
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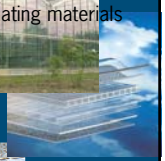
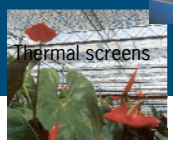
  - …

Step 2: Functions and working principles

- Region: Northern and Southern Europe
- Required functions:
  - Energy supply
  - Heating
  - Dehumidification/cooling
  - CO_2 supply
  - Reduction of energy loss
  - Additional light
  - …
  - …

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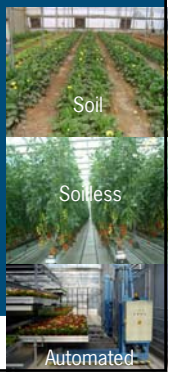
  - Reduction of energy loss
  - Additional light
  - Growing systems
  - …



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- Region: Northern and Southern Europe
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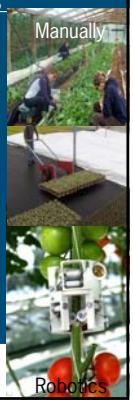
  - Reduction of energy loss
  - Additional light
  - Growing systems
  - Labour



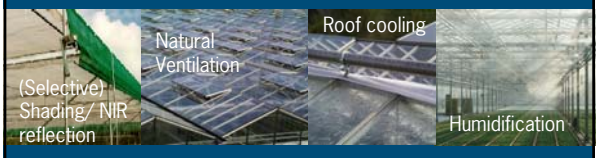
Design example: Energy efficient greenhouses

- Objectives for energy conservative greenhouse in North west Europe:
  - Low energy input
  - High production and quality
  - Yearround production
- Major design challenge:
  1. Winter/fall: maximize solar radiation and minimize energy loss
  2. Spring/summer: energy efficient cooling

Challenge 1: Maximize use of solar energy

- Increasing cover slope (South Europe)
- Minimized construction parts: e.g. no ventilation system: +1.5%
- Greenhouse orientation
- Ideal covering material
- Cleaning!

Challenge 2: Efficient cooling



Challenge 4: Sustainable energy (geothermal)

Strengths of geothermal energy:

- highly sustainable
- stable costs
- applied in relatively simple technology
- high availability, low maintenance

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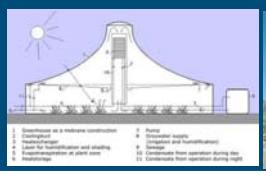
Future challenge: Electricity producing greenhouse

- 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 (20 kWh/m² per year)

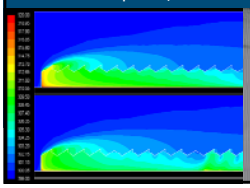
Design example: Water saving greenhouses

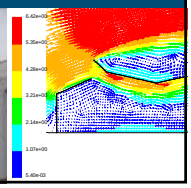
- Example WATER efficient greenhouse system
- Closed greenhouse for South Europe (Watergy)
  - Maximum water and energy use efficiency
  - Aim: + 30% production



Design example: Low cost passive greenhouses

- Example Southern Europe (Spain/ Italy)
  - Unheated, low cost
  - Reduce temperatures under high radiation
  - Uniform conditions in summer
  - Ventilation: major process in heat transfer
  - Area, shape and position of openings, rate of opening
  - Wind speed / direction

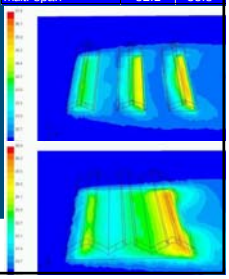




Design example: Low cost passive greenhouses

- Example Asia (Indonesia)
  - Unheated
  - Low cost
  - Tropical lowland conditions
  - Reduced water use
  - Reduction of plant diseases
  - Improved quality

Configuration	3 m/s wind	No wind
single greenhouses	31.3	33.5
	31.4	33.6
	31.3	33.6
multi-span	32.1	33.8



Design example: Low cost passive greenhouses

CONCLUSIONS

- The design of efficient greenhouses in general requires:
  - optimization of the greenhouse as a solar collector
  - improved production by better control and expanding the growth season
- For NW Europe focus on:
  - more airtight greenhouses with cooling, heat recovery and optimized environmental control
- For Southern Europe:
  - efficient natural ventilation and reducing the solar energy flux into the greenhouse during summer
- Final design strongly related to (local) conditions and economic feasibility

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Adaptive greenhouse design:
for optimal results world wide

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