ZINEG: the Project on Energy Consumption in Greenhouses

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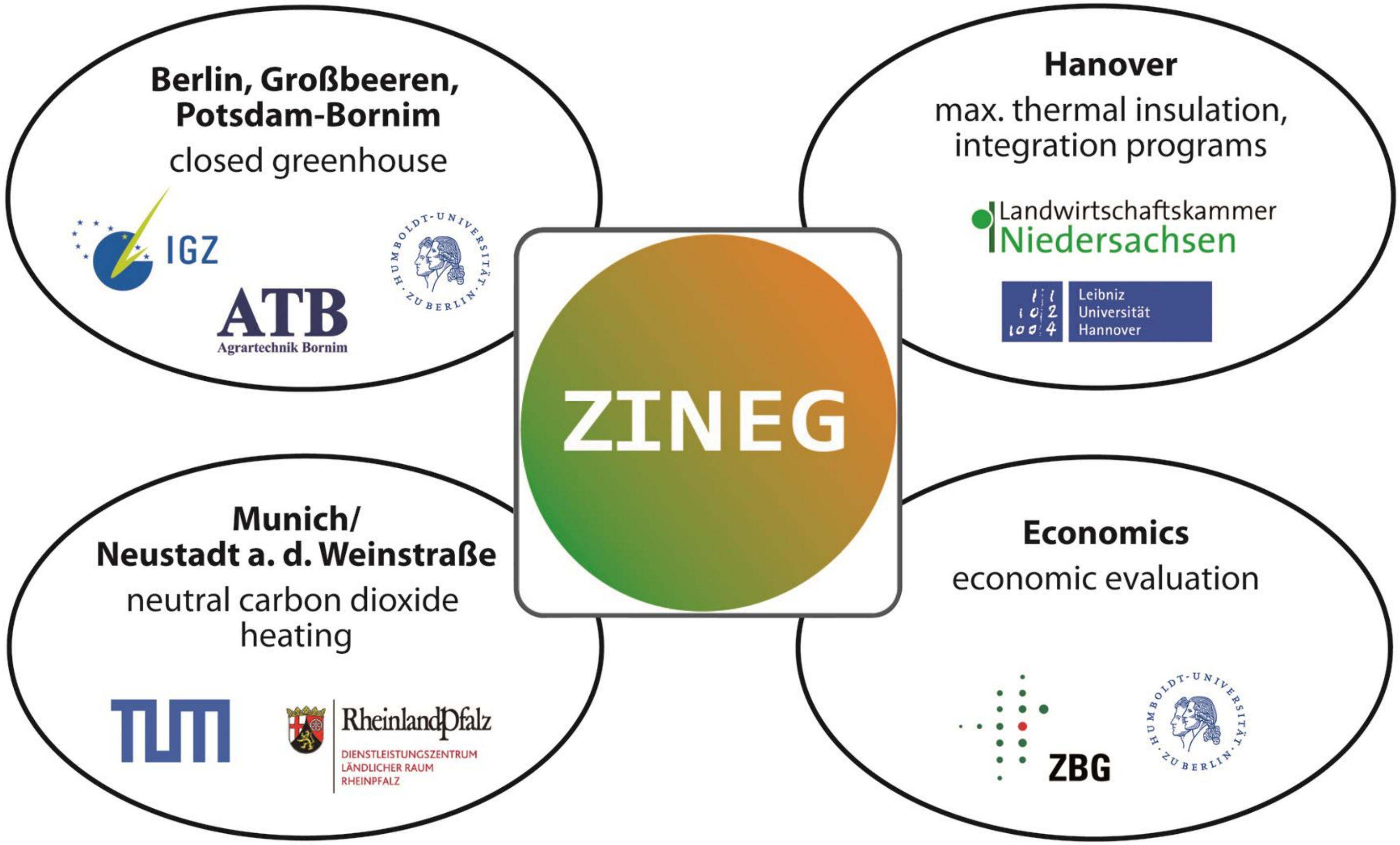
ZINEG THE LOW ENERGY GREENHOUSE



Public relations

Association for Technology and Structures in Agriculture (KTBL)

www.zineg.net

KTBL Kuratorium für Technik und Bauwesen in der Landwirtschaft

Aim of ZINEG

- „The gerneral Aim of th ZINEG-Project between 2009 und 2014 was to prove and develop Technologies for a Plant Production in Greenhouses which can lower down the Use of fossile Energies and so the fossile CO_2- Output nearly to Zero.“ (Quelle: ZINEG.net)

General Aims

- < Energy Consumption
  - – Mostly without fossile Energy
  - – Mostly without fossile CO_2- Emissions
- System-oriented Approach to reduce Energy-Consumption
  - – Combination of energy saving Procedures with culture Procedures

Quelle: Meyer, J.: Hortivienna - ZINEG- Vortrag, Wien, 2013

Line of Action

- 4 different Concepts – Flowers/Vegetabl.
- Common:
  optimal Insulation of Greenhouse Cover
  - double Materials / /heat Protection Glass
  - multiple Thermal Screens
- Heat supply in the canopy
- New Concepts for Regulation – integrativ
- Comparison with Standard Cultivation
  - comparative study with Climate-Control

Quelle: Meyer, J.: Hortivienna - ZINEG- Vortrag, Wien, 2013

Procedure

- Harmonisation Measure Methods
  - Energy-Consumption
  - Climate-Measurements
  - Plant-Physiology
- Cultivation in Experimental Stations like normal nurseries
- Portability of Results directly possible – Lighthouse- Projects

Quelle: Meyer, J.: Hortivienna - ZINEG- Vortrag, Wien, 2013

4 Greenhouse-Concepts

Hannover – Leibnitz University
& LWK Niedersachsen

Osnabrück- University

Berlin, Humbold-University

TU München & DLR Rheinpfalz,
Schifferstadt / Neustadt

Zineg Berlin

2 4-Sector Greenhouses-Venlo Type a 307 m², Hight of Gutter 6 m Side-walls 2 Layers, Roof 1 Layer Glass,Tomato-Production in high Gutters, hydroponic; Collector-House: 2 Screens 1* Daylight, 1 High Alu screen, Sidewalls-Rolling screen
Reference: 1 Screen daylight on top

Quelle: U. Schmitd, HU Berlin, ZINEG 2012

ZINEG Berlin Collector-House

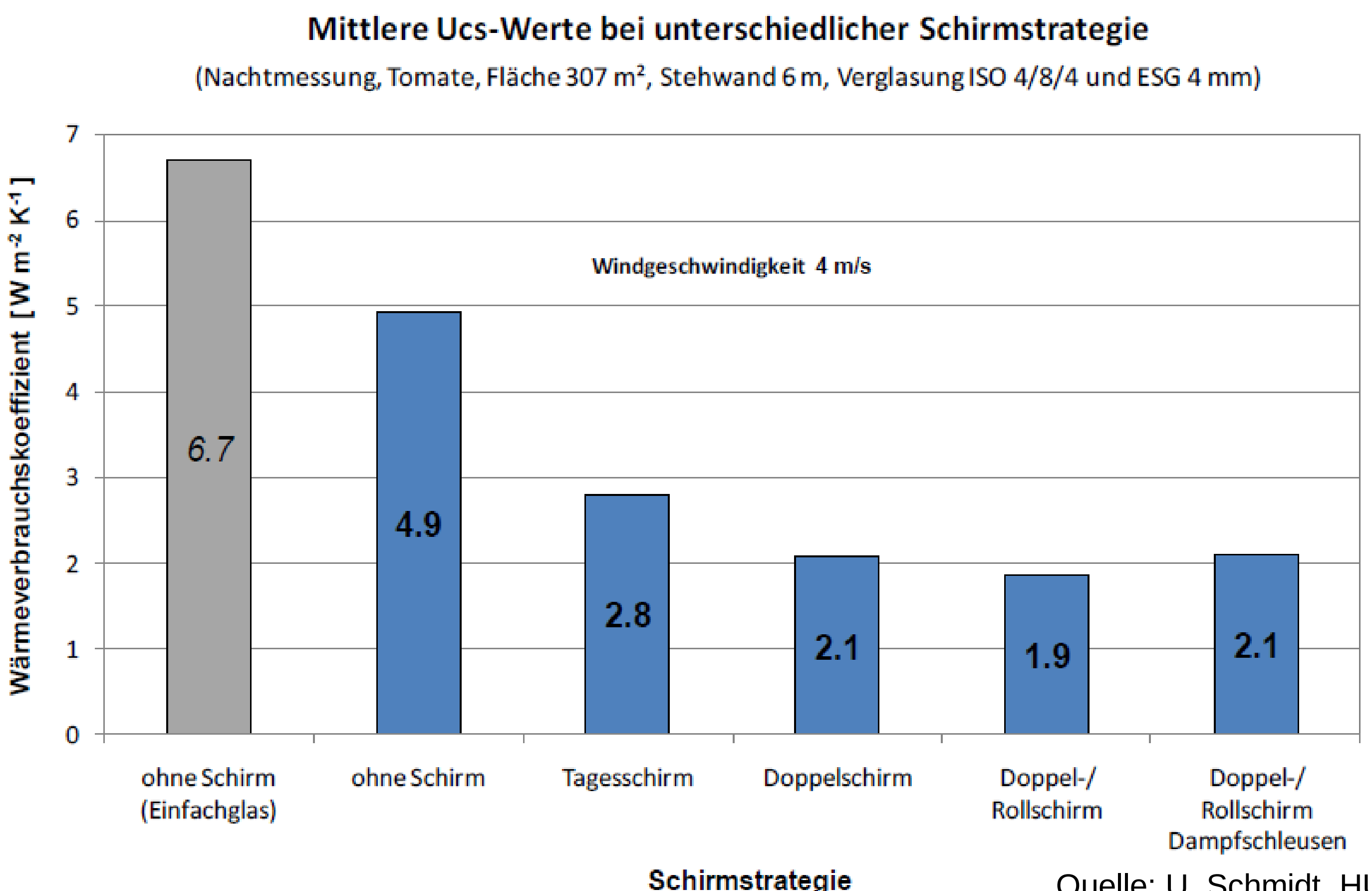
- Single & double Layer Glass;
  6,7 m Hight on Top
- Thermal Screen & low grade Shading screen
- Closed System (Ventilation)
- Active Solar Storage (Water-tank)
- Use of an Heat-Pump
- Active Cooling in the Greenhouses
- Gutter-Cultivation in Substrate-Bags

ZINEG Berlin Collector-House

- Active Cooling via finned Tubes*
- Humidification via Fog-System
- Low grade Shading screen
- Energy-Screen *
- Foil-Tubes for Heating & CO_2
- Heating Pipes in the Canopy
  (* installed only in Collector - House)

Results Energy-Consumption

Ucs – different screen strategies



Standard = 7,6 W/m²K; Reference = 6,7 W/m K; Collector House = 4.9 W/m²K; Daylight Screen = 2.8 W/m² K; Double Screen = 2,1 W/m²K; Roof & Side-Screen = 1,9 W/m² K; Dehumidification with Screens = 2,1 W/m²K

Quelle: U. Schmidt, HU Berlin, ZINEG 2012

View on Heat-Pump

Eine 40 kW Elektro-wärmepumpe (133 W/m²) kann eine Heizleistung von 110 kW (370 W/m²) erbringen.

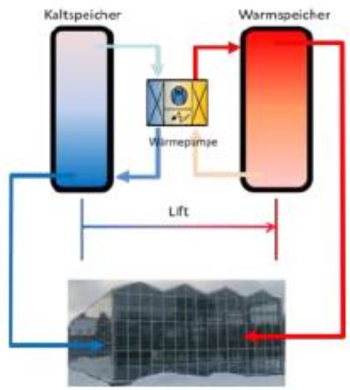
Damit können beide Gewächshäuser mit je 180 W/m² bei einer Außen-temperatur von -14 °C auf 20 °C beheizt werden.

Die projektierte Kühlleistung liegt bei 80 bis 100kW (340 W/m²).

Quelle: U. Schmidt, HU Berlin, ZINEG 2012

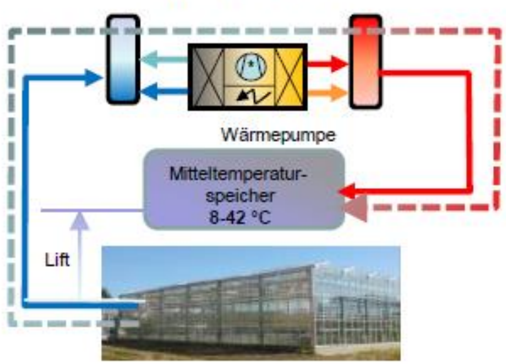
Function Heat Pump

Chancen:
- höhere Arbeitszahlen
- geringere Isolations-aufwendungen,
- multivalente Nutzungs-möglichkeiten für den Speicher

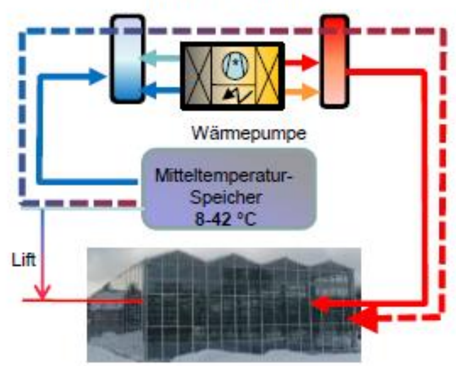


Risiken:
- Platzbedarf für Speicher,
- Speicherkosten,
- höherer Installationsaufwand

Direct Buffer Installation



Gewächshaus kühlen
Speicher laden



Gewächshaus heizen
Speicher entladen

Indirect Buffer Installation by hydraulic turnouts
(d: Weichen)

Quelle: U. Schmidt, HU Berlin, ZINEG 2012

Heat Pump

In the Collecror-House the Heat-Pump may fulfill different tasks:

1. Cooling with Heat Pump (HP)
2. Cooling without HP
3. Cooling for Drying the Air
4. Heating with HP
5. Heating without HP

Quelle: U. Schmidt, HU Berlin, ZINEG 2012, verändert

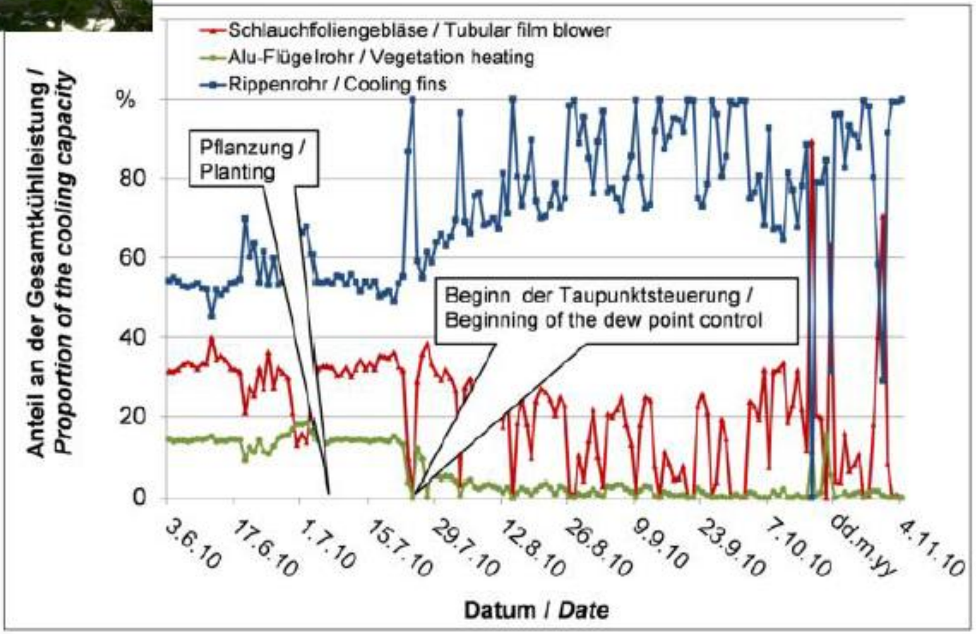
Efficiency of Cooling-Systems

Rippenrohre unter dem Dach

Finned Tubes under the roof

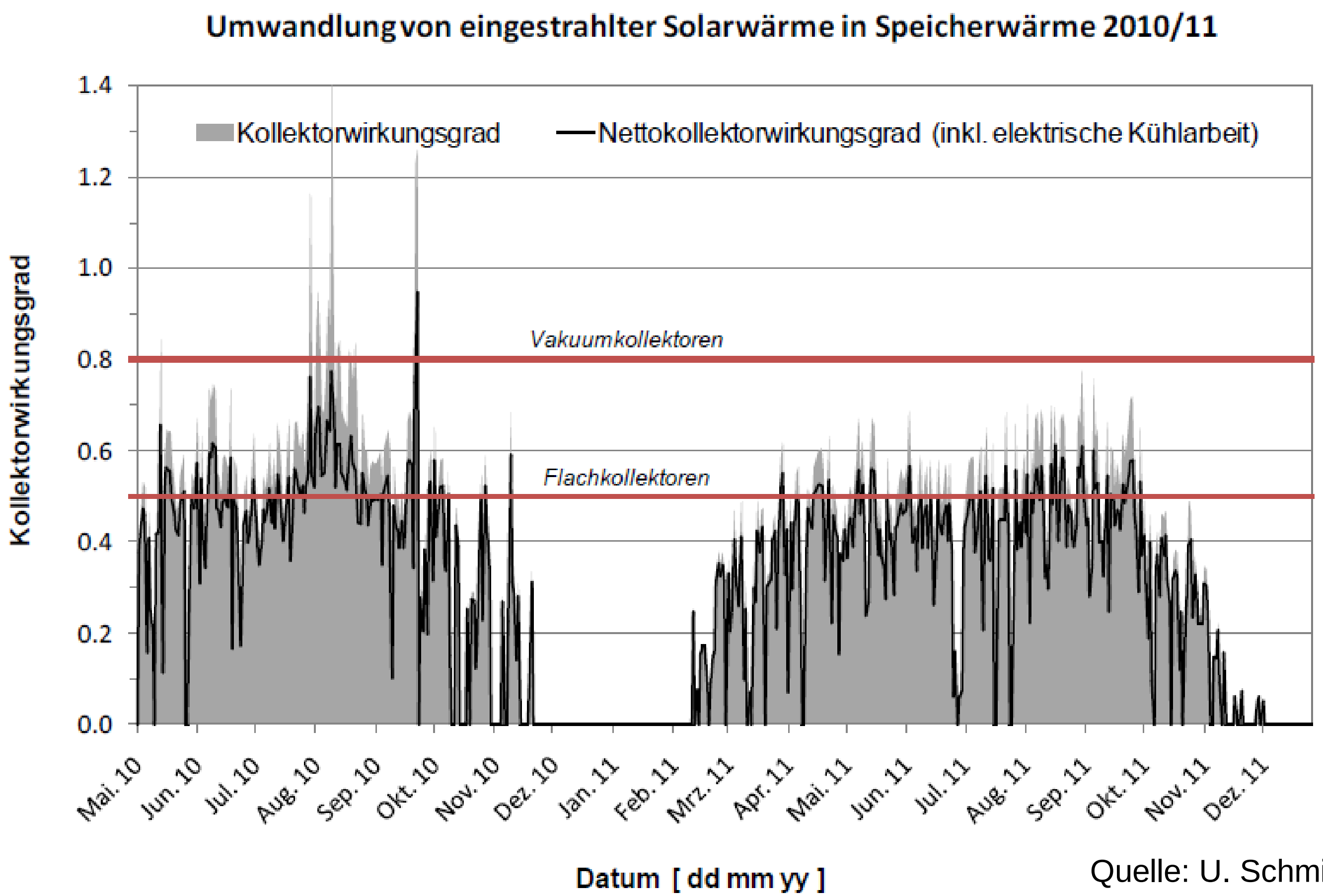
Chancen:
- hohe Kühlleistung,
- hohe Konden-satleistung
- gleichmäßige Temperatur-verteilung,
- geringer Elektroenergie-bedarf

Risiken:
- höhere Anforderungen an Statik,
- höhere Kosten,
- Lichteinbußen



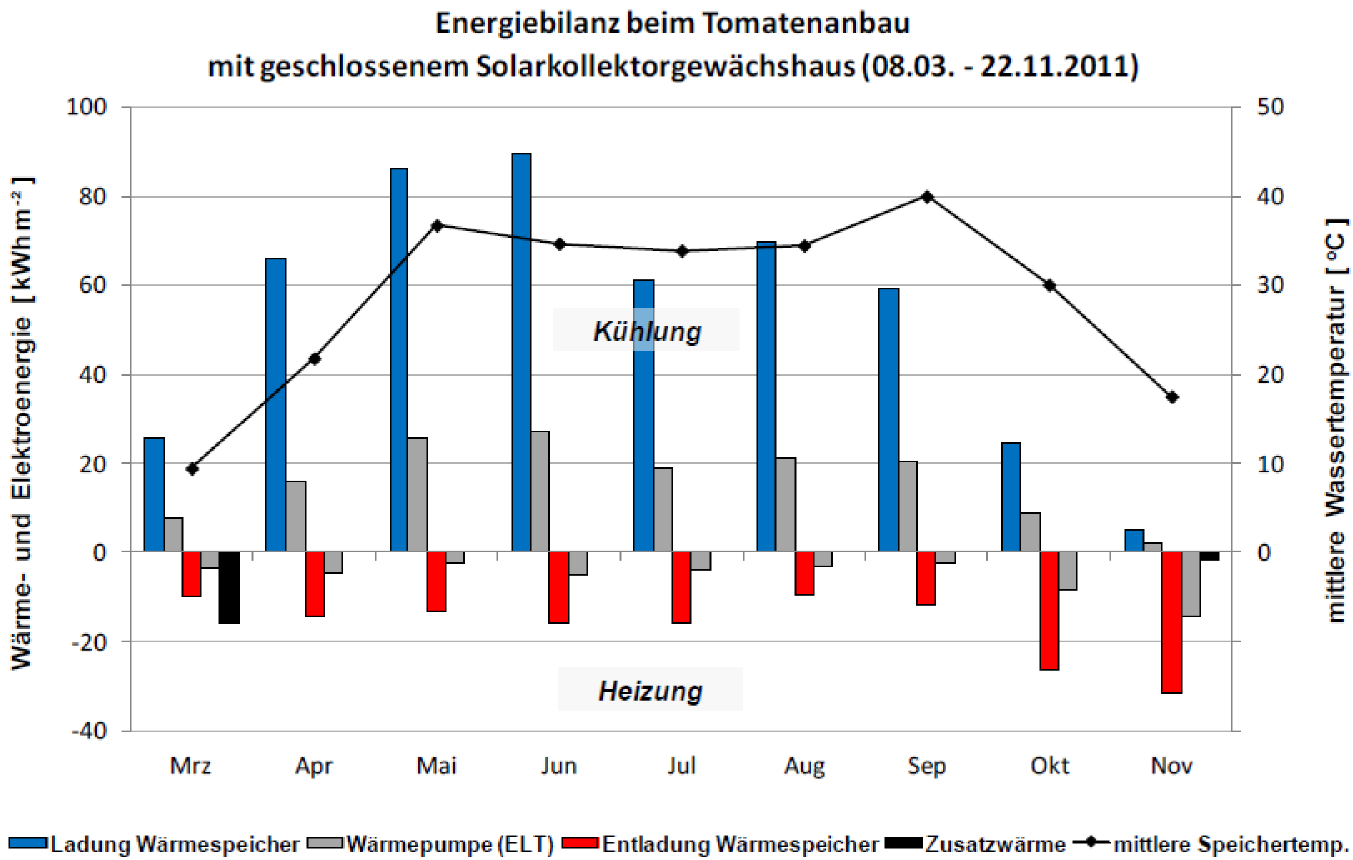
Quelle: U. Schmidt, HU Berlin, ZINEG 2012

Greenhouse as a Solar Collector



Quelle: U. Schmidt, HU Berlin, ZINEG 2012

Greenhouse as an Energy-Collector



Blue:
Input to Buffer
Grey:
Power HP
Red:
Out from Buffer;
Black:
External Heat;
Black Line:
Ø Temperature of Buffertank

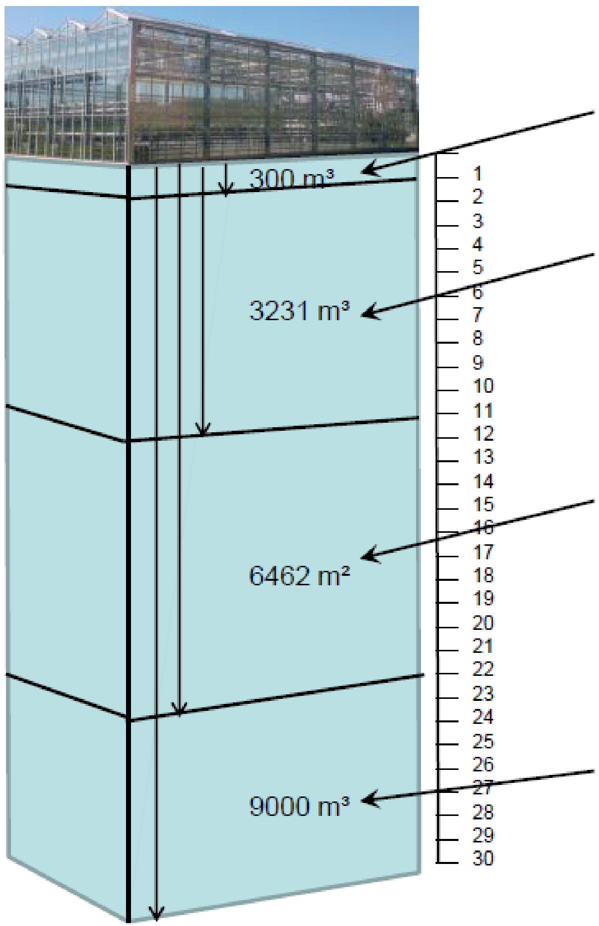
Quelle: U. Schmidt, HU Berlin, ZINEG 2012

Results Heat Pump

- 1 kWh Electricity powers
- Heating: 4,4 kWh Heat
- Cooling: 5,5 kWh Coldness
- Correction with Efficiency of Power Plant (0,385):
- Heating: 1,7
- Cooling: 1,9

Quelle: U. Schmidt, HU Berlin, ZINEG 2012

Size of Buffer Tank



Im Berliner Zineg-Projekt wird die Wärmeenergie in 1 m^3/m^2 gespeichert…

Will man die 150 MWh, die im Jahr 2011 gewonnen wurden speichern, so benötigt man ca. 11 m^3/m^2

Würde man die gesamte überschüssige Solarwärme des Jahres 2011 speichern (Kollektorwirkungsgrad = 1) wären 22 m^3/m^2 erforderlich

Nach Aussagen niederländischer Experten werden in Aquiferspeichern ca. 30 m^3/m^2 benötigt[1]

Quelle: U. Schmidt, HU Berlin, ZINEG 2012

1: F. De Zwart, mündliche Mitteilung 2009

Low-Cost Heat-Buffer

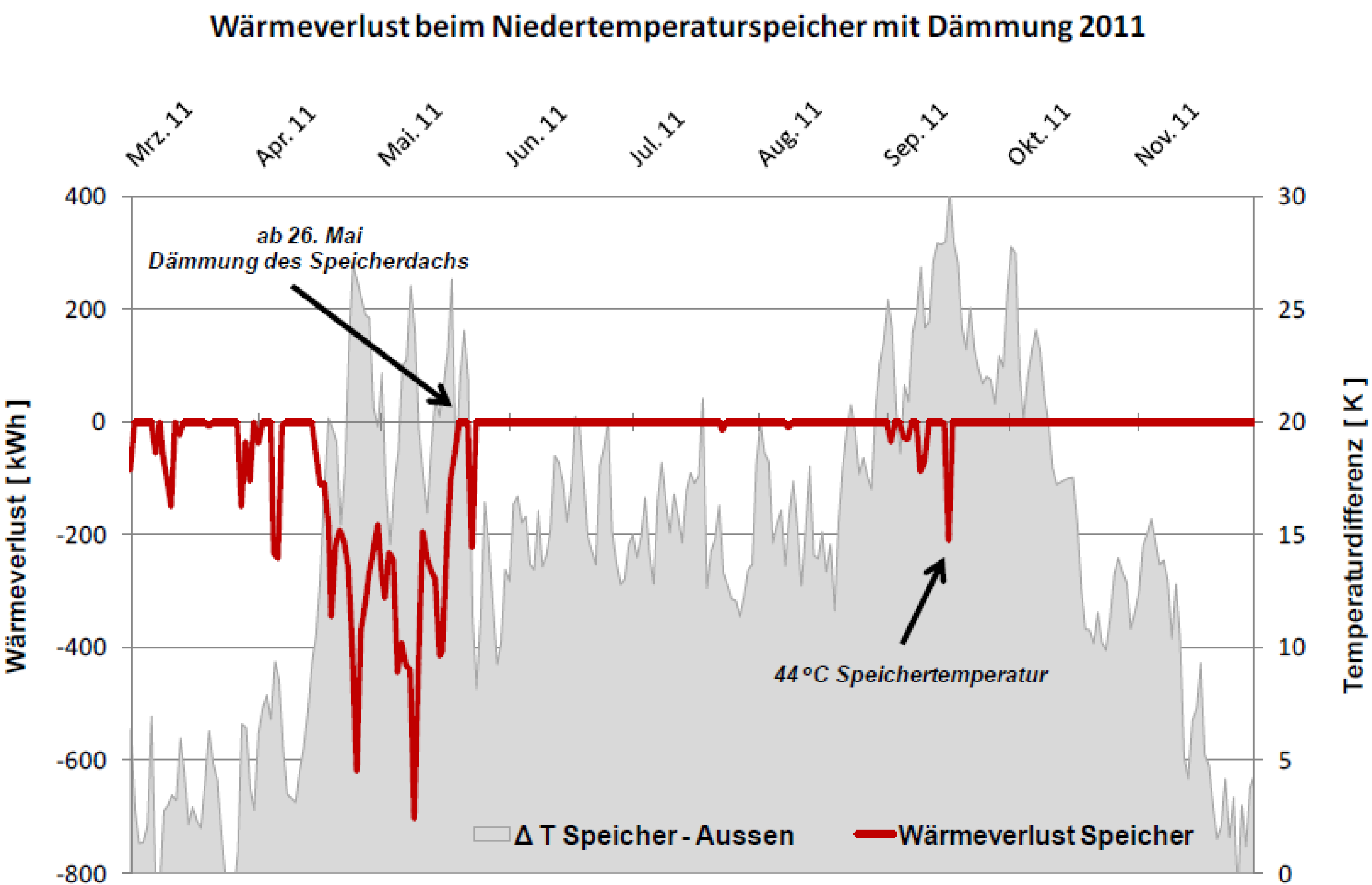
Das Wasser wird oberirdisch in Wassertanks gespeichert, die gleichzeitig als Regenwasserrückhaltebecken für die Bewässerung genutzt werden können.

Das Fassungsvermögen beträgt 260 m^3 (0,85 m^3/m^2 oder 30 kWh/m^2)
Damit kann eine Wärmemenge von 10 MWh gespeichert werden.

Die Temperatur pendelt zwischen 5 °C (Speicher entladen) und 45 °C (Speicher geladen)
Die Speicherkosten betragen 80 €/m^3 (ohne Isolation) und 120 €/m^3 (mit Minimalisolation)

Quelle: U. Schmidt, HU Berlin, ZINEG 2012

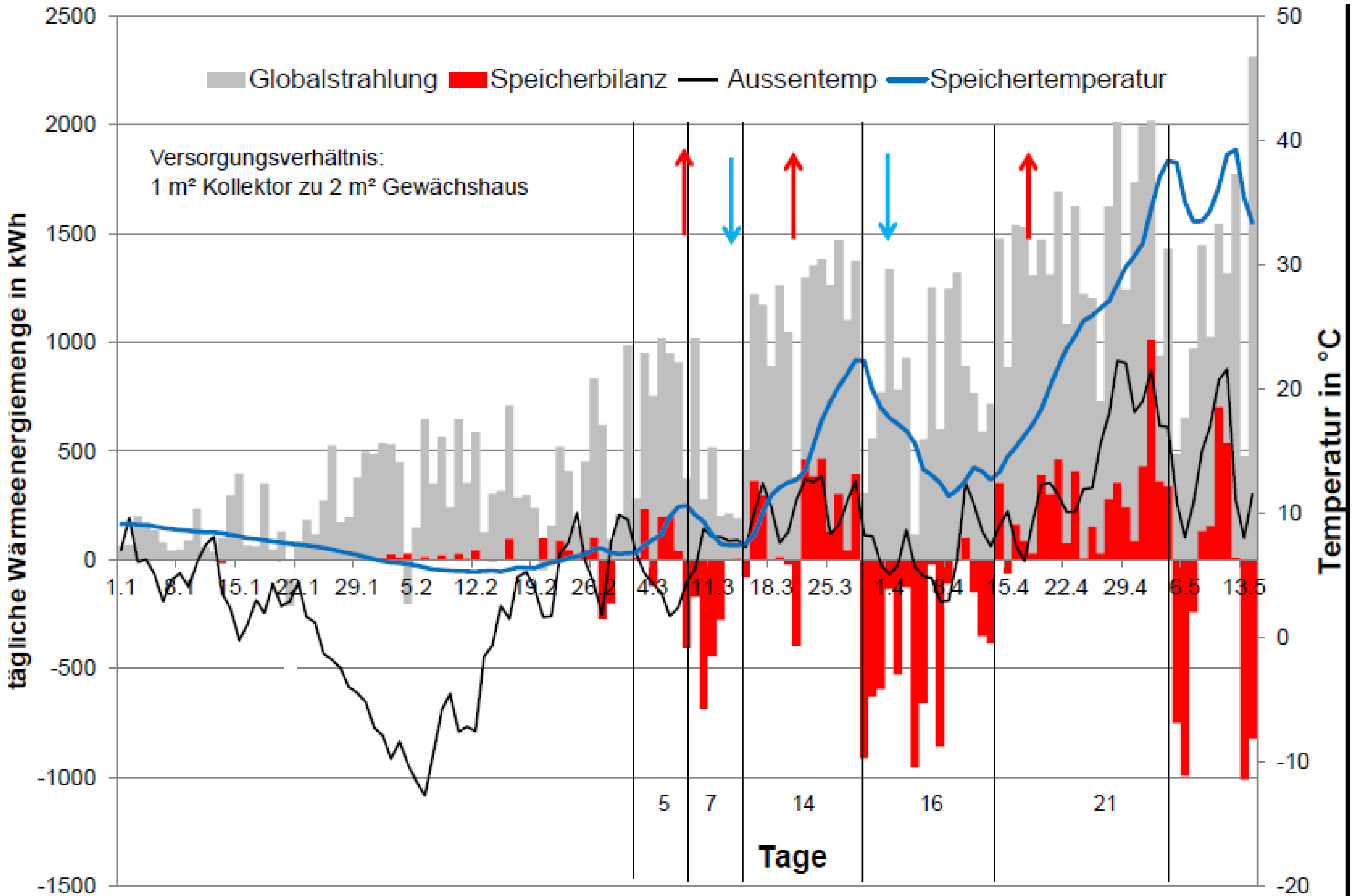
Heat-Storage Results
Energy Loss



Gray: Temperature-Difference Storage – Outside Air (K)
Red: Energy Loss (kWh)

Quelle: U. Schmidt, HU Berlin, ZINEG 2012

Storage Results



Gray: global Radiation (kWh);
Red: Buffer-Bilance (kWh);
Black Line: Air-Temperature (°C):
Blue Line: Storage – Temperature (°C)

Quelle: U. Schmidt, HU Berlin, ZINEG 2012

Tomatoe-Production Berlin

Quelle: U. Schmidt, HU Berlin, 2014

PHYTomonitors
Measurements in Vitro

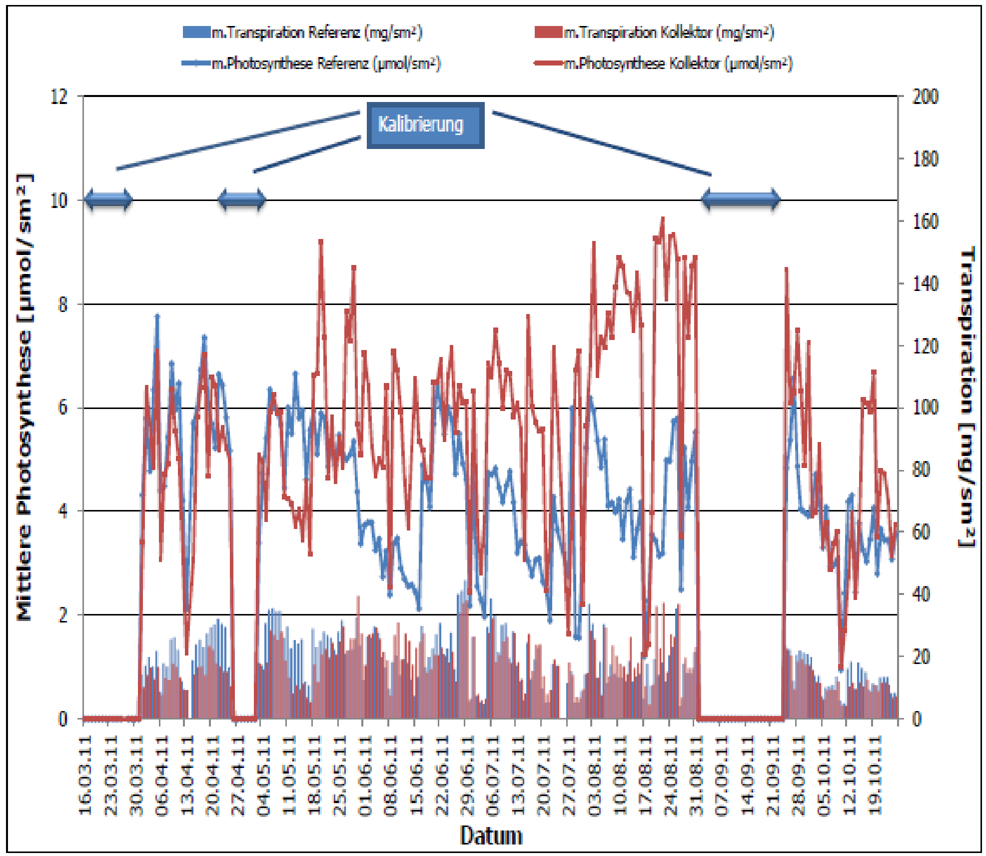
PHYTomonitors = Design & Concept: Humbold-University, U. Schmidt

Quelle: U. Schmidt, HU Berlin, ZINEG 2012

Photosynthesis & Transpirtion

Ergebnisse des Versuches 2011

Mit Hilfe der Phytomonitore konnte eine deutlich höhere Nettophotosynthese (+33%) und eine verminderte Transpiration (-9%) im Kollektorgewächshaus gemessen werden.



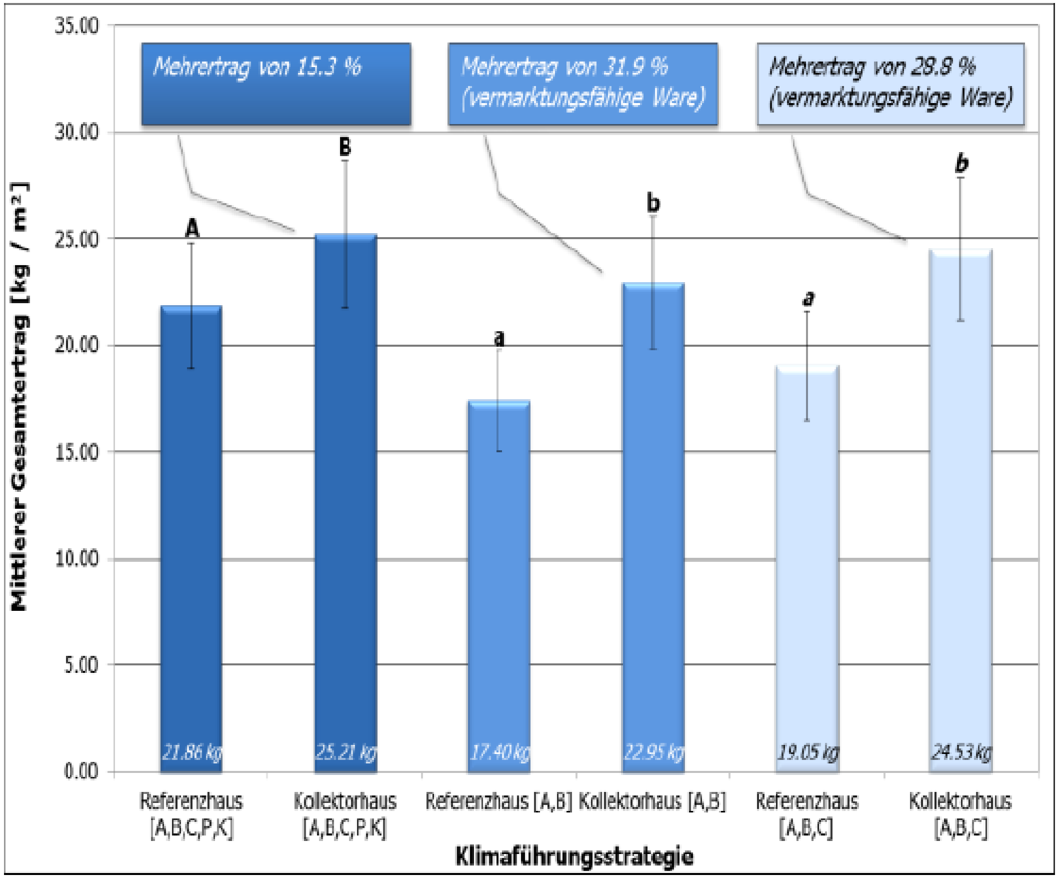
Results of 2011: Netto-Phytosythesis + 33 % in Collector-House; Transpiration 9% Lower than Reference-House

Quelle: U. Schmidt, HU Berlin, ZINEG 2012

Results 2011

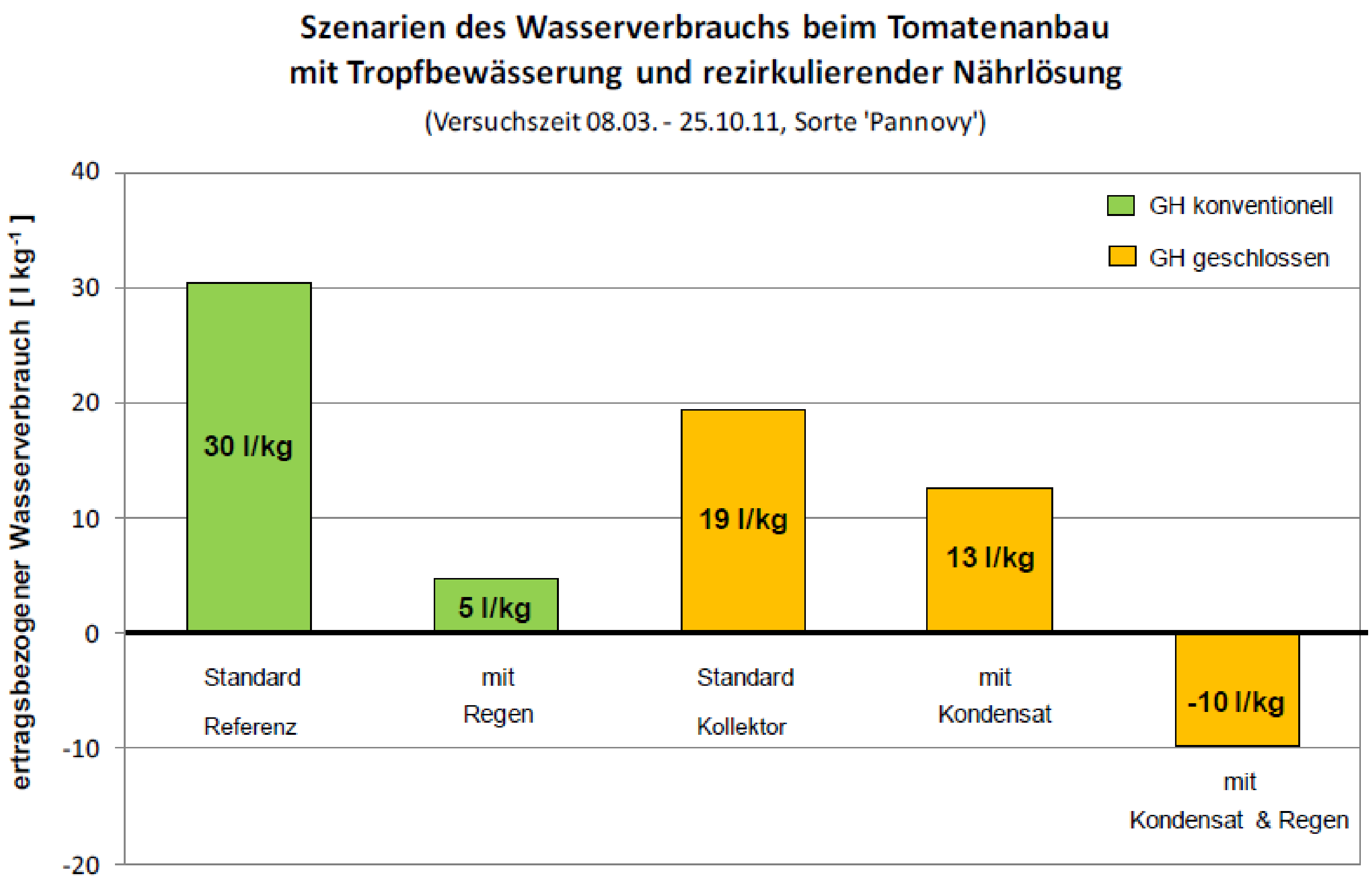
Aus dem Versuch 2011 (Mai bis November) konnte ein Mehrertrag von 29 bis 32 % aus dem Kollektorgewächshaus ermittelt werden…

Tomato Crop in Collector-House 29 – 32 % greater than in Reference-House (marketable fruits)



Quelle: U. Schmidt, HU Berlin, ZINEG 2012

Water-Use Closed System



Green Reference

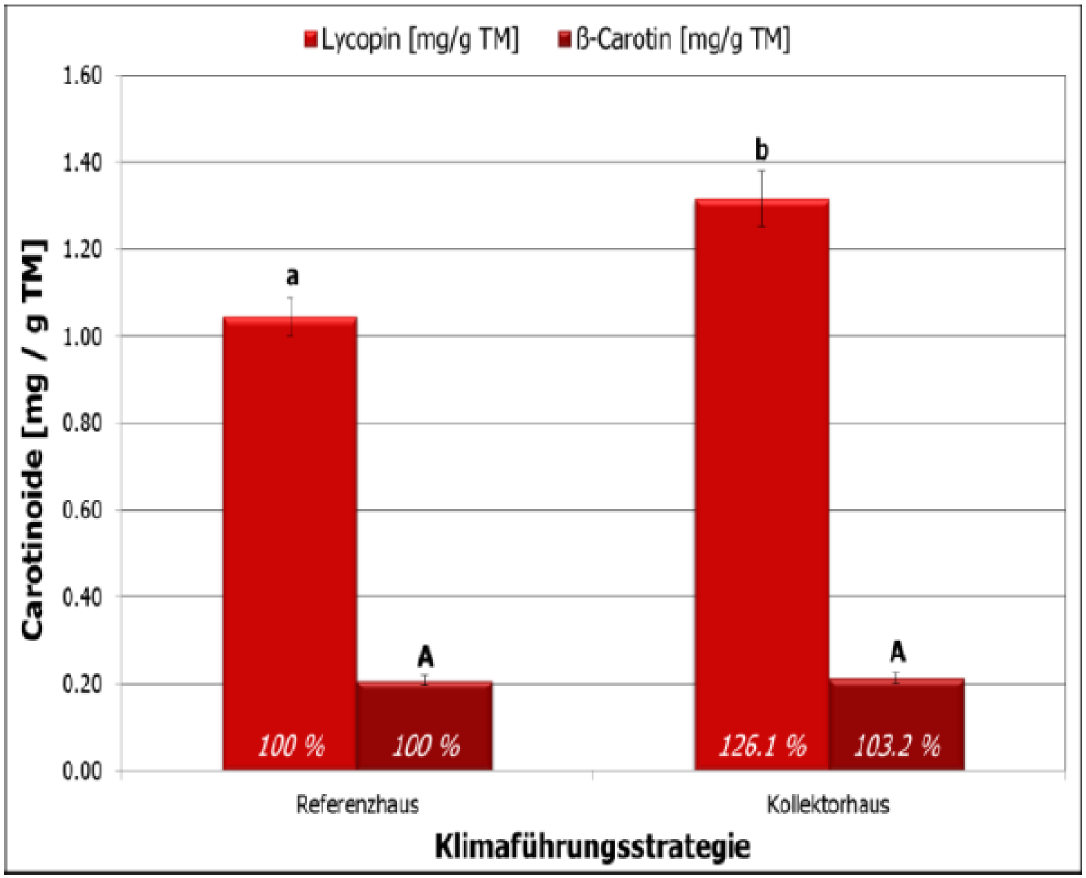
Yellow: Collector House – Closed System

Rain Water Use possible

Quelle: U. Schmidt, HU Berlin, ZINEG 2012

System- Effects

Die Tomatenfrüchte aus dem Kollektorgewächshaus haben höhere Gehalte an den gesundheits-förderlichen Inhaltsstoffen Lycopin und ß-Carotin



The tomatoes in Collector house have a higher content on Lycopin (left) and ß-Carotin (right)

Quelle: U. Schmidt, HU Berlin, ZINEG 2012

Hannover-Project

- Greenhouse with maximum Insulation,, Closed House Strategy, Solar Use & Integrating Strategies

- Culture: Ornamentals (Pots)
- Partners:
  - Landwirtschaftskammer Niedersachsen,
    Lehr- und Versuchsanstalt für Gartenbau, Hannover-Ahlem
  - Leibniz Universität Hannover,
    Fachgebiet Biosystem- und Gartenbautechnik

Quelle: J. Mayer, TUM, 2013

View on Greenhouse & Heat-Storage, Hannover

Quelle: J. Mayer, TUM, 2013

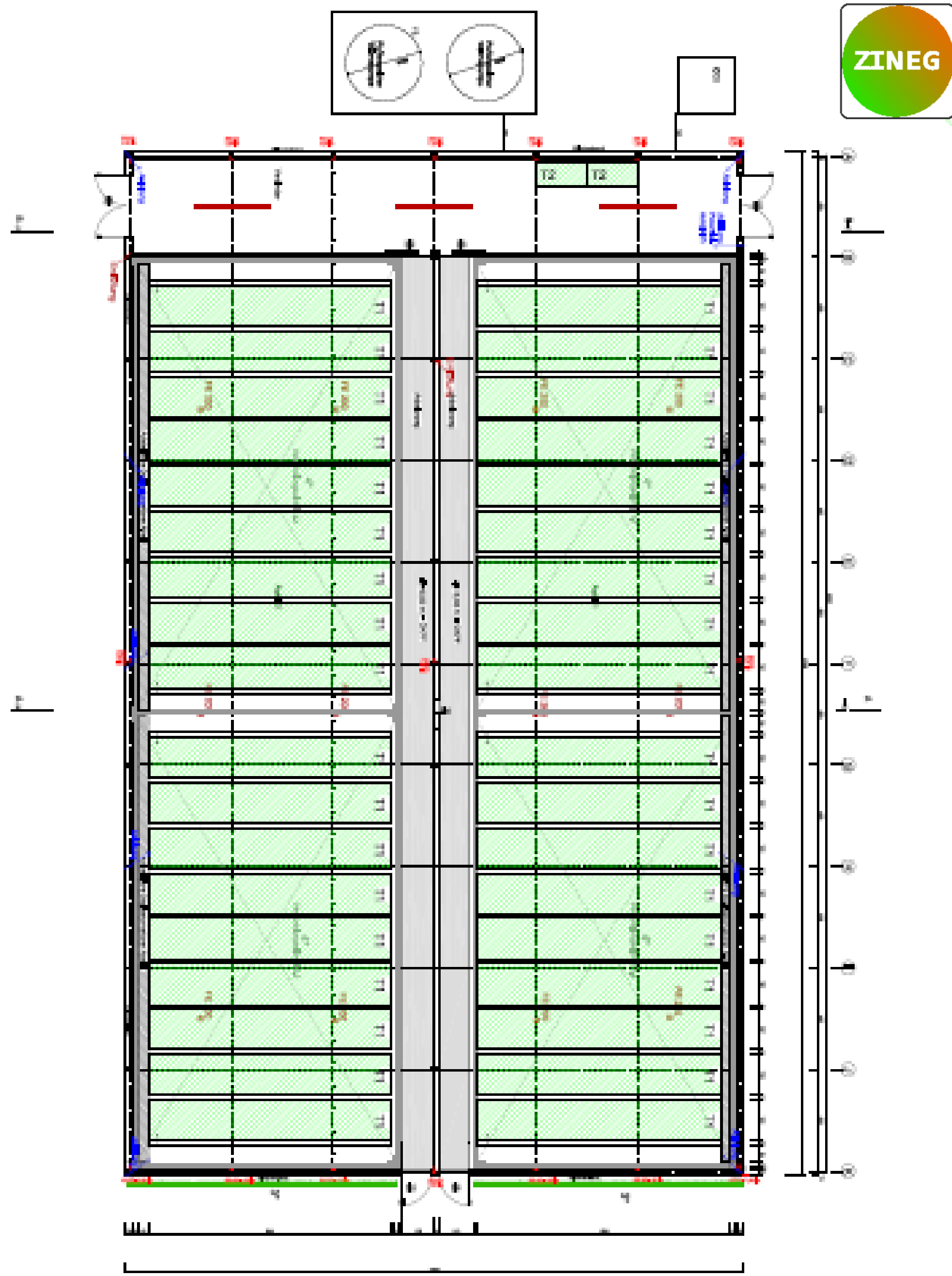
Schwerpunkt Hannover

Systemorientierter Ansatz

- Kultur: Topfpflanzen
- Anlagenkonzept:
  - Isolierverglasung
  - Dreifach-Energieschirm
  - möglichst geschlossene Betriebsweise mit CO_2-Düngung
  - Solarenergienutzung mit Tag-Nacht-Speicherung
  - Integrationsregelstrategien
- angepasste Kulturprogramme
- Phytomonitoring

Quelle: J. Mayer, TUM, 2013

Hannover Plan



Grundriss

Dimensions:

40 x 24 m = 960 m^2

2 Departments
(Ventilation)

4 Unterabteilungen
Verdunkelung
(Heizung/Kühlung)

Quelle: Gefoma, 2009

Roof Material

Exspectations:

- high Light-Transmissivity
- good Insulation

Technical Solution:

- Insulating Glass with Anti-Reflexglass (AR-Glass)
- Plexiglas-4-skin sheet on all Sides

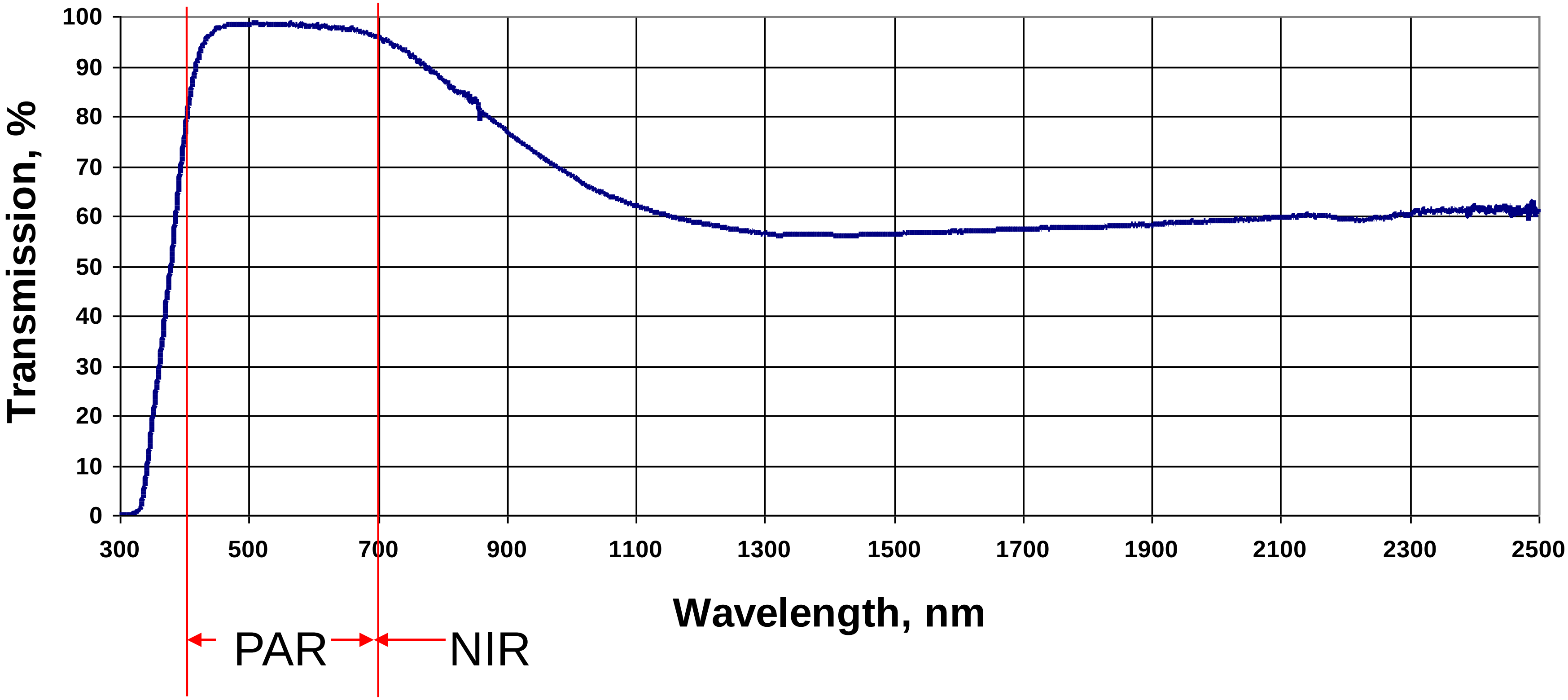
Problems:

- Raise of Air-Humidity

Quelle: J. Mayer, TUM, 2013

Roof- Glass

GroGlass
(hohe PAR- und niedrige NIR Durchlässigkeit)



Properties thermal Screens

Exspectations:

- ➢ No Light-loss during daytime
- ➢ No leaks, if closed by night

Technical Solution:

triple theermal Screen

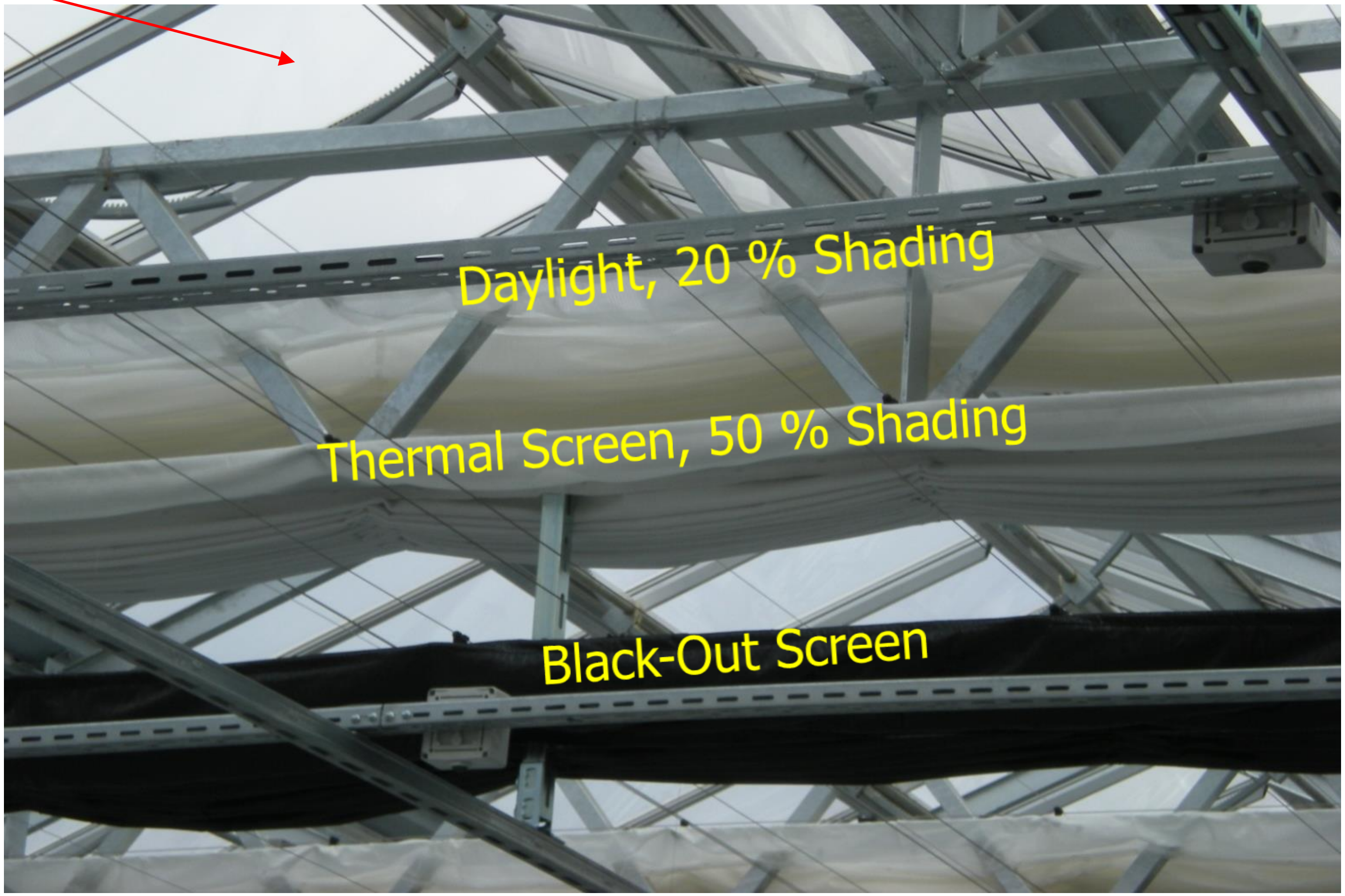
- •Light transmittig Material (Daytime-screen) SHS 15 in B1 (Novavert)
- •Tissue with Alu: Pyro Silver 50 in B1 (Reimann)
- •Blackout screen XLS Obscura Revolux in B1 (Ludvig Svensson)

Problems:

- Air-Humidity

Energy-Saving-Installations Hannover:

Insulating Glass + triple Screens



Quelle: J. Mayer, TUM, 2013

Use of solar Energy

Exspectations:

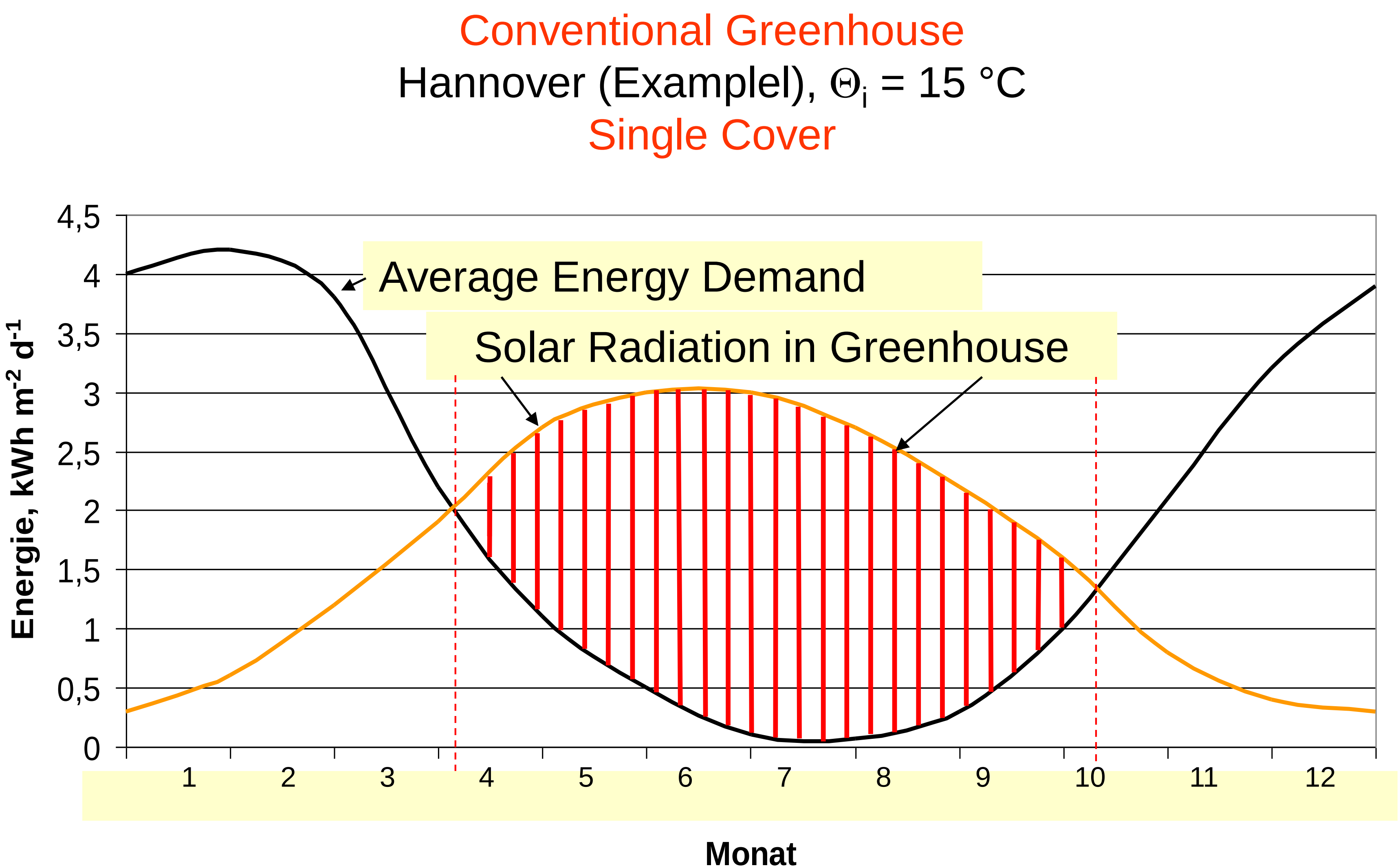
- Long-term CO_2 Dosage
- Climate-Regulation to plant demand

Technical Solution:

- Venting as late as possible (CO_2-Dosage)
- Low Temperature Heat Exchangers
- Storage of solar Energy in insulated Waterbuffers (Day-Night-Storage)

Quelle: J. Mayer, TUM, 2013

Energy-Demand & Solar Radiation



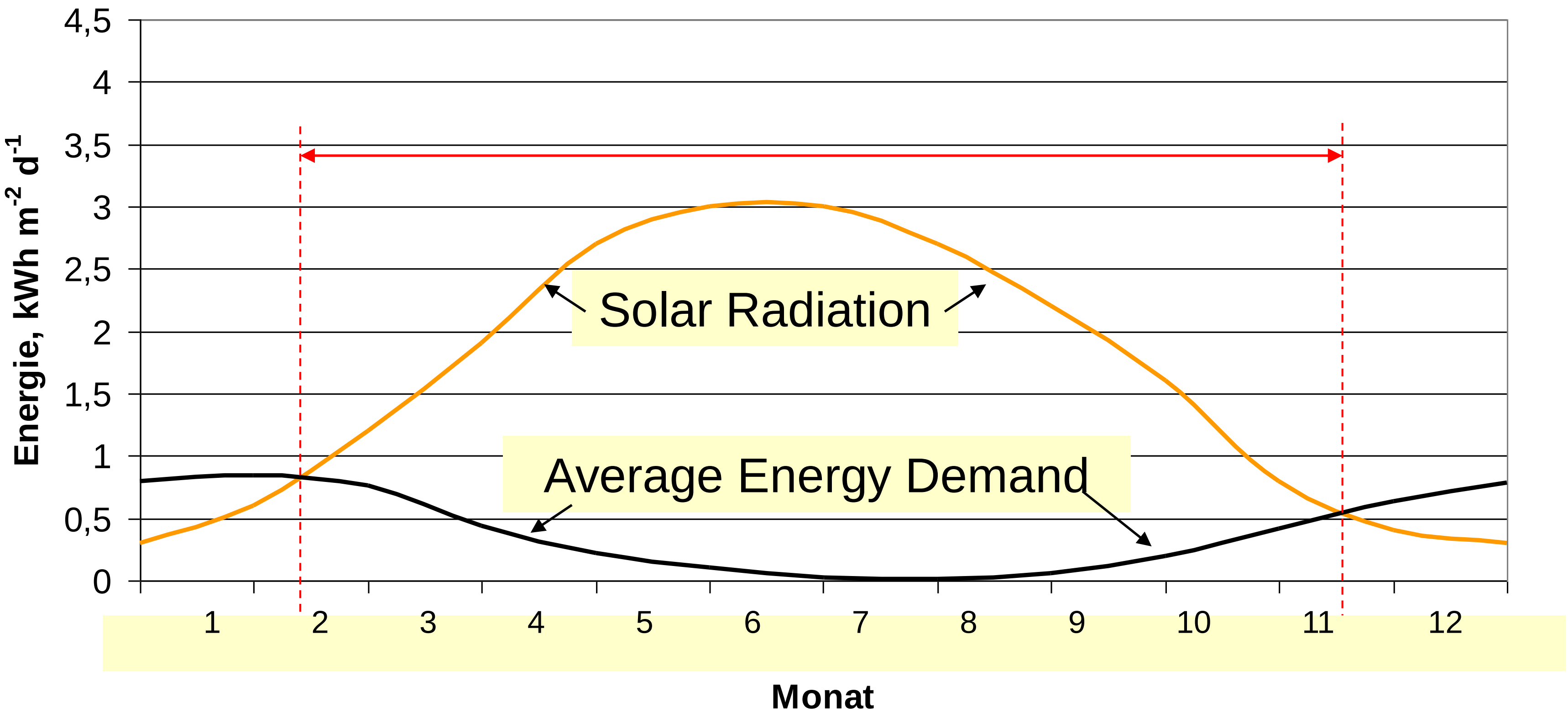
Quelle: J. Mayer, TUM, 2013

Energy-Demand & Solar Radiation

Low-Energy-GreenhouseHannover (Beispiel),

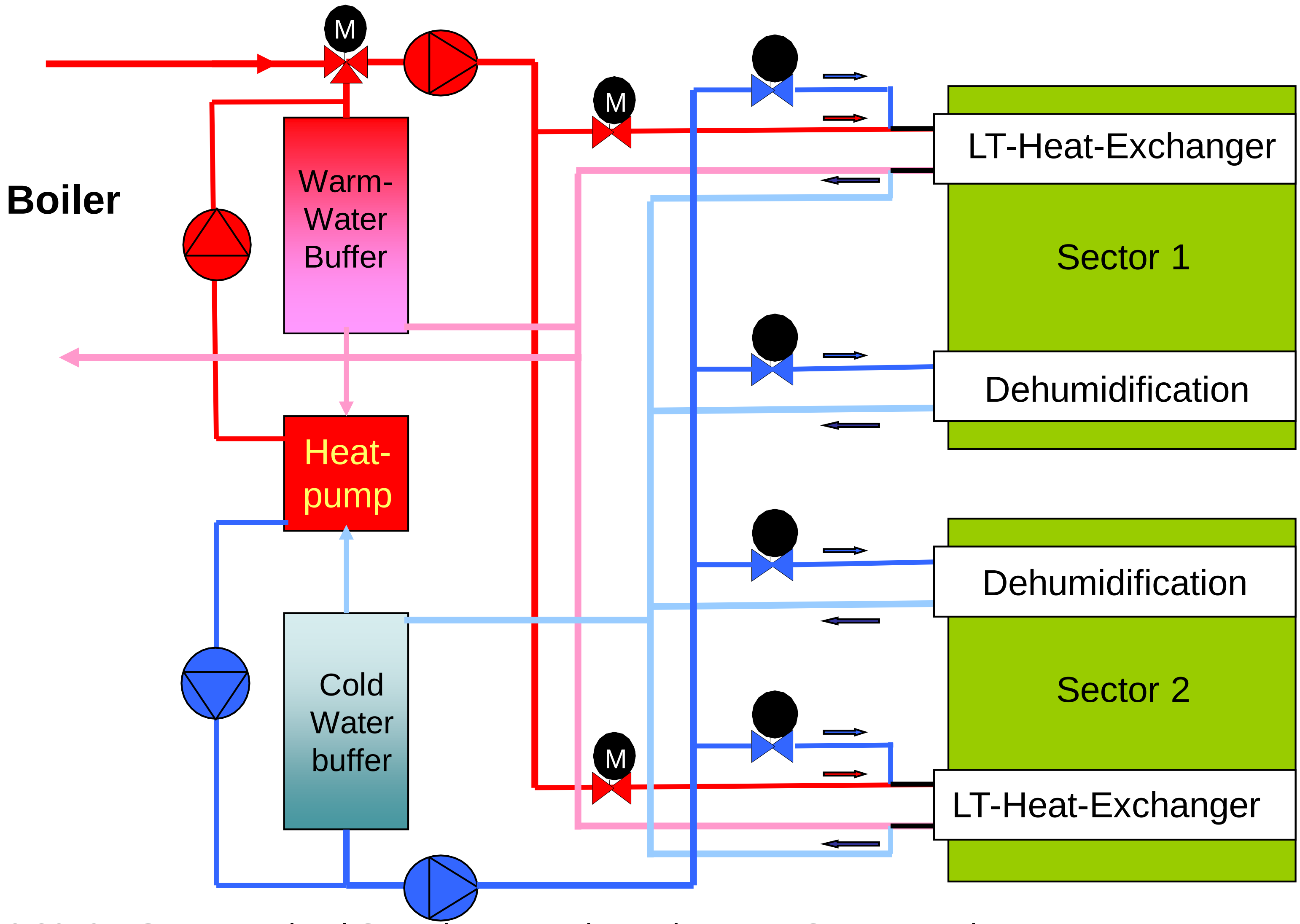
Θ_i = 15 °C

Insulating Glass, triple Screen



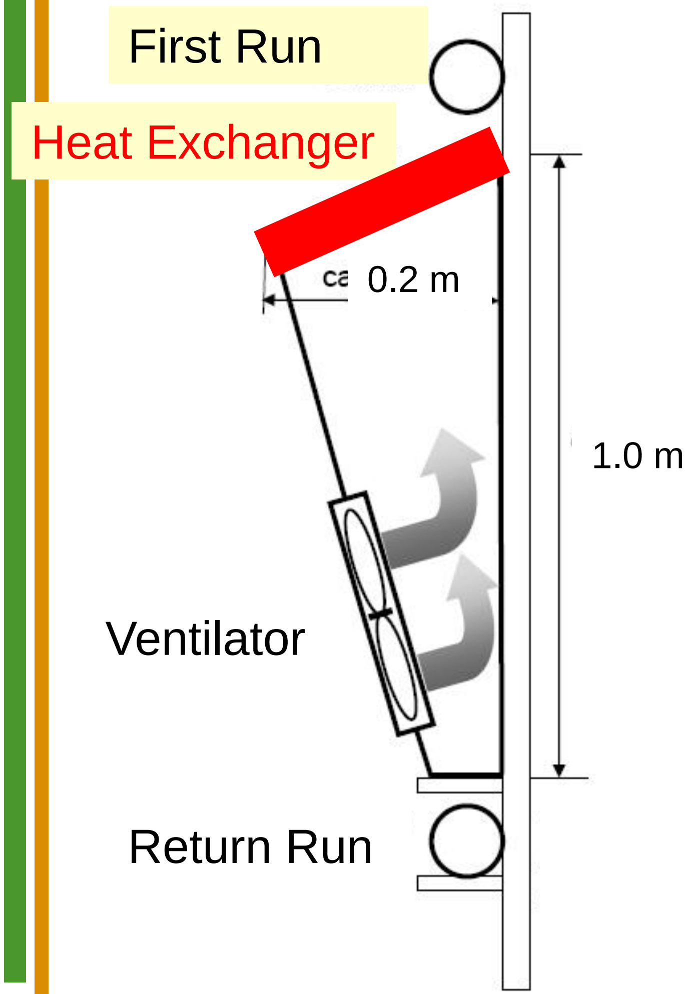
Quelle: J. Mayer, TUM, 2013

Hannover Storage Scheme



Quelle: J. Mayer, TUM, 2013

Low Temperature (LT) Heat Exchanger



Quelle: v. Elsner, 2009)

Storage & Heat Pump

Quelle: J. Mayer, TUM, 2013

Results of Measurements on Heat Consumption Hannover

Insulated Glass & triple thermal Screens

Energy Savings (By Night) in Comparison to
Insulated Glass &/ Single Glass with 1 Screen (40 % Saving)

Kind of Insulation	measured	Saving	Saving
	U_{cs}-Wert	Insulating Glass U_{cs} = 4,0	Single Glass + 1 Screen U_{cs} = 4,6
	W m^{-2} K^{-1}	%	%
Insulated Glass	4,0	0	14
Insulated Glass & daylight Screen	3,0	27	38
Insulated Glass & 2 Screens	2,1	47	54
Insulated Glass & 3 Screens	1,2	70	74

(Tantau 2012)

Results of Measurements on Heat Consumption Hannover

Insulated Glass & triple thermal Screens;
Ratio of latent Energy on Heat Consumption

(Assumption: No Condensation, inner Energy-Transfercoeffizient h_i = 8 W m^{-2} K^{-1};
with Condensation h_i = 14 W m^{-2} K^{-1})

Type of Insulation	U_{cs} measured	Part of latent heat
	W m^{-2} K^{-1}	%
Insulating Glass	4,0	17,7
Insulating Glass + Daylight-Screen	3,0	13,8
Insulating Glass + two Screens	2,1	10,1
Insulating Glass + three Screens	1,2	6,0

(Tantau 2012)

ZINEG

Calculated

Transpiration m_{tr}, Blatt θ_{le}, Bedachung θ_{si} , θ_i = 20 °C, θ_e = 0 °C, LAI = 3; A_s/A_g = 1,5)

Roof-Material	U_{lat} W m^{-2} K^{-1}	θ_{si} °C	θ_{le} °C	m_{tr} g m^{-2} h^{-1}
Single Glass	**6.7**	6.7	18.5	47.1
Insulating Glass	**3.2**	13.3	19.2	28.5
PMMA "Alltop" 16 mm	**2.6**	14.4	19.3	24.5
PMMA 32 mm, 4-Layers	**1.7**	16.4	19.5	16.7
Thermal-Stop Glass	**1.1**	17.6	19.7	11.9
Single Glass & Screen	**3.4**	3.4	18.8	45.4
Single Glass & 3 Screens	**1.3**	1.5	19.3	31.0
Insulating Glass & 3 Screens	**1.1**	4.8	19.4	27,7

(Tantau 2012)

Summary – measurements of Energy-Consumption (static)

ZINEG

- **Insulating Glass & 3 Screens**

  → 70 % Energy-Saving in Comparison to Single Glass + Screen
- **Latent Heat:** Share by potplants 30 bis 60 %,

  Low Influence on heat Consumption by maximum Insulation - Low
- Clear Reduction of Transpiration
- Screens: in Comparison higher Transpiration

Quelle: J. Mayer, TUM, 2013

Plant results with *Euphorbia pulcherrima* (Horscht, 2011)

- Potting CW 28, Trimming CW 30 to 5 - 6 Stems (CW = Calendar Week)
- 12-cm Pot, final Density 12 Pflanzen/m^2
- 5 Cultivars (Premium Red, Mira Red, Champion Red, Christmas Eve, Freedom Early)

	Temperaturvarianten				
	Niedrigenergiegewächshaus				**Standard**
	1	**2**	**3**	**4**	**5**
Langtag KW 28-39	16°C HT, 22°C WR, 26°C LT **Ø TMT 21,7°C**				KW 33 20°C HT, 22°C LT KW 34 16°C HT, 20°C LT **Ø TMT 19,9°C**
Kurztag ab KW 40	verdunkelt ab KW37	unverdunkelt	verdunkelt ab KW 37	unverdunkelt	unverdunkelt
	12°C HT, 20°C WR, 26°C LT		**16°C HT**, 20°C WR, 26°C LT		18°C/16°C HT, 20°C/18°C LT

HT = heating Setpoint TMT = average Day Temperature
LT = Ventilation Setpoint
WR = heat recovery

Quelle: J. Mayer, TUM, 2013

Kulturversuch mit *Euphorbia pulcherrima* (2011)

Cultivar : 'Freedom Early'

Quelle: J. Mayer, TUM, 2013

pictures 30.11.2011

Plant results with *Euphorbia pulcherrima* (Horscht, 2011)

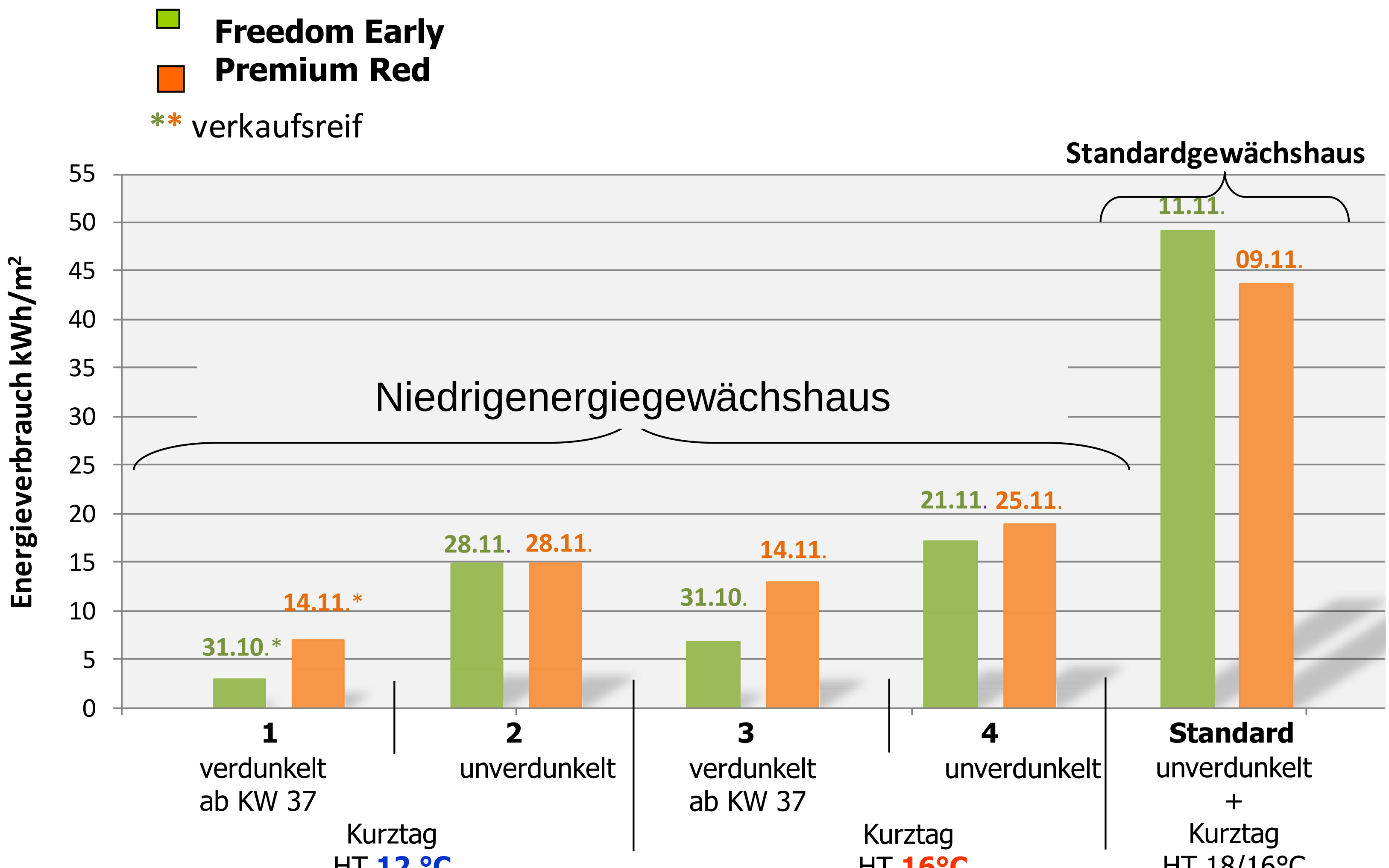
Cultivar : 'Premium Red'

Quelle: J. Mayer, TUM, 2013

pictures 30.11.2011

Results with *Euphorbia pulcherrima* (2011)

Energy-Consumption by different Treatments



Quelle: J. Mayer, TUM, 2013

Results with *Euphorbia pulcherrima* (Horscht, 2011)

ZINEG

Summary – System-Technical Investigations

- Energy-Saving: 62 % bis 85 %
- **Good to very Good Plant Quality**
- Reduced Evapotranspiration
  → Adaption of Watering & Fertilisation
- Higher Air-Humidity: No phytosanitarian Problems
- Ligt-Loss: No Influence on Output / Harvest

Quelle: J. Mayer, TUM, 2013

Recommendations for the Grower:

- Abstinance to active Solarenergy-Use:
  - Too low Workload, Energy-Need from March to October low
  - Ammount of Electrical Power for Low-Temperature Heat Exchangers & Heat Pump
- Passive Solar-Uuse is very effective (ca. 12 K by Night)
  - Energy-Storage in the Ground etc.
- Actions to Energy-Saving:
  - Roof Two-Layer Plates (Alltop) (Insulating Glass AR-coatet Price?)
  - Sides Three-Layer Plates (S3P)
  - Three Screenes, small Packages, supported on Wires
  - Temperature-Sum-Strategies

Quelle: J. Mayer, TUM, 2013

Recommendations for the Grower:

Changed Growing Conditions:

- Raised Air-Humidity:
  - Irrigation-System with dry Table Surfaces at Night (Ebb & Flood)
  - Cultivate more dry
  - Dehumification-Strategy via Heating, Screens & Heating & Ventilation
- lowerTranspiration
  - Lower Water input
  - Adopt Concentration of Fertilizers
- Light-Loss
  - Konstruction with high transmissivity
  - Small Screen-packages, Integration in the Construction
- CO_2-Concentration:
  - CO_2-Enrichment

Quelle: J. Mayer, TUM, 2013

ZINEG Greenhouses at Osnabrück Hochschule

Only Change: Glass to WSG (Heat-Protection-Glass)

By that :

lower Energy-demand, smaller Heating-System,
no upper Pipe-Heating (No Radiation from above)

lower Radiation – lower Transpiration?
Lower Water Consumption ?
adjusted Fertilizer-Concentration ?
Less Shading needed ?

Cultures: Pot-Ornamentals, Vegetables (later)

ZINEG Greenhouses at Osnabrück Hochschule

- Abandonnement to Light (> 80 %, U-Wert 1,1)

-high Insulation

-> Possible saving of Energy to ca. 70 % at ca. 20 °C Setpoint

- Mostly simpel Strategy- one Material for all Sides‘ =
- Heat Protection Glass

72% Netto-Culture-Area – Aim: High Air-Humidity

Quelle: J. Mayer, TUM, 2013

ZINEG Greenhouses at Osnabrück Hochschule

- Venlotype
- Ventilation Opening on full Lenght
- Basic Size: 12,0 m * 12,0 m
- Hight of Gutter 4,0 m
- Shading: Thrmal Screen on Top
- Rolling Screens on East-, South- & Westside
- Ebb- Flood- Tables

Quelle: J. Mayer, TUM, 2013

ZINEG Greenhouses at Osnabrück Hochschule (from South)

Quelle: J. Mayer, TUM, 2013

ZINEG Greenhouses at Osnabrück Hochschule

Monitoring Greenhouse (Ko)

- Snowload 0,25 kN/m²
- 4 mm Floatglass
- Lattice Profile: Sapa Variolux 16

Hating-System:

- Pipe heating under the Tables
- Convector
- high Pipe heating

Quelle: J. Mayer, TUM, 2013

ZINEG Greenhouses at Osnabrück Hochschule

Experimental House (WSG)

- Snow-Load 0,75 kN/m²
- 26 mm Heat Protection Glass:
  - Semco Star S Ug= 1,1 W/m²K
- Lattice Profile: Sapa Variolux Termo 26 Profile

Heating-System

- Pipe heating under the Tables
- Convector

Quelle: J. Mayer, TUM, 2013

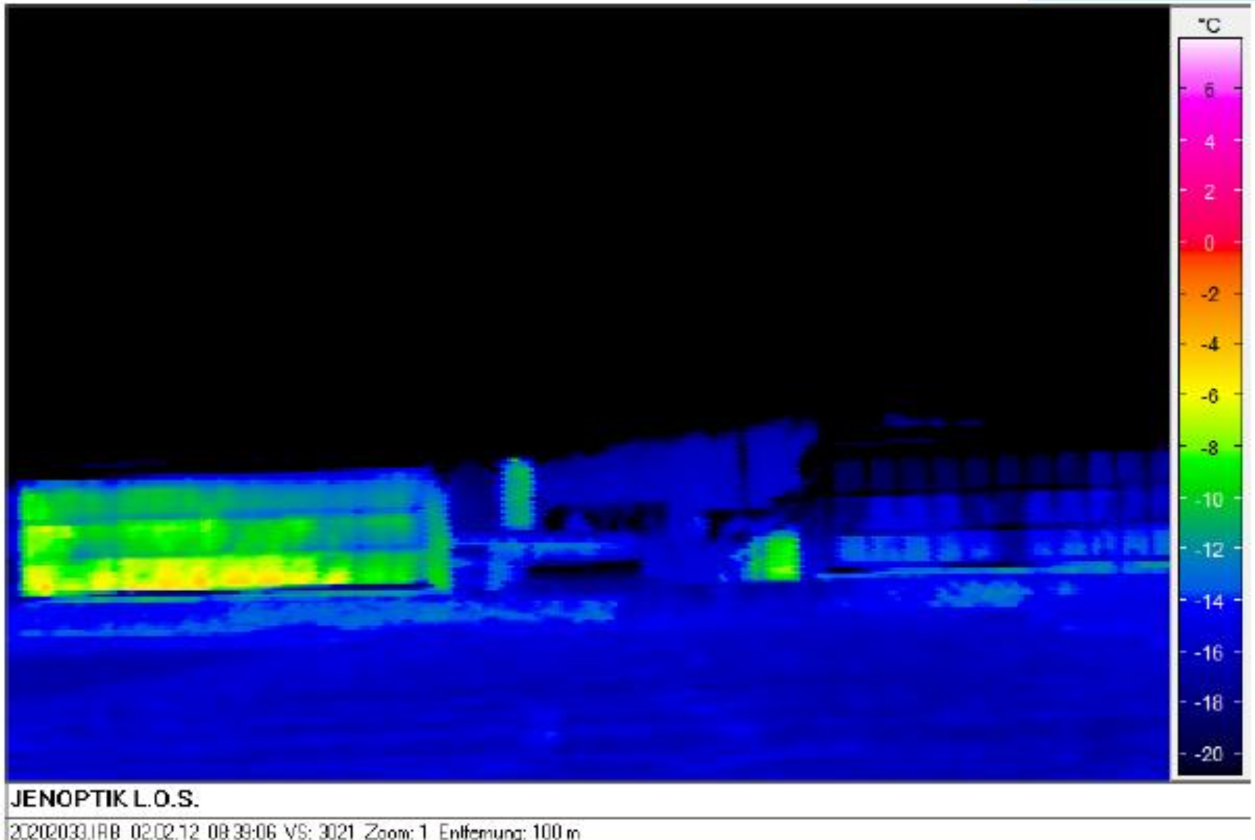
ZINEG Greenhouses at Osnabrück Hochschule

Monitoring (Ko)

Experimental (WSG)

Quelle: J. Mayer, TUM, 2013

Osnabrück- Zineg Greenhouses

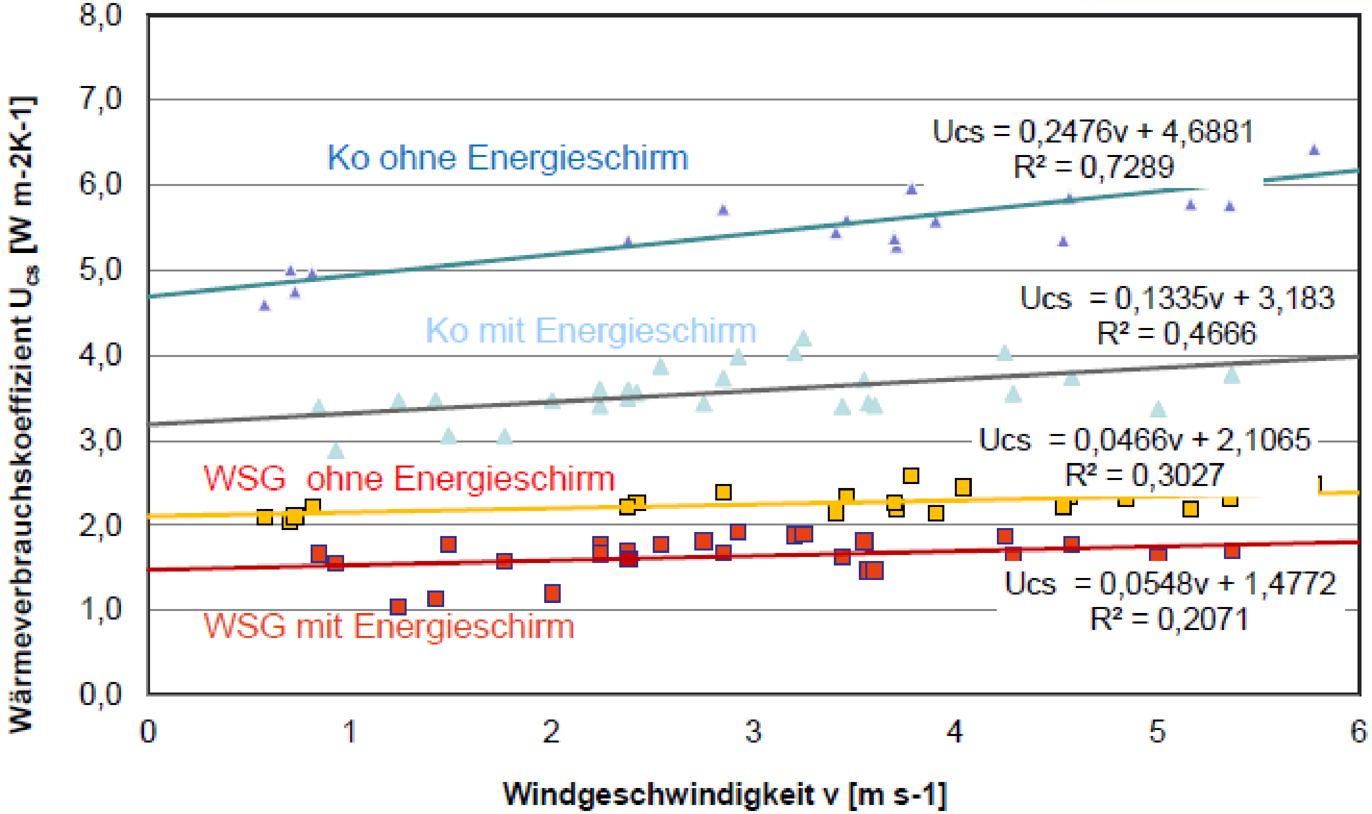


Thermal Photo of the Greenhouses in a Winter-Night

Quelle: H-P. Roemer, ZINEG, 2012

Osnabrück ZINEG Results

Energy-Consumption



Quelle: H-P. Roemer, ZINEG 2012

Light-Reduction WS- Glass

Transmissivity Glass = 80 % (Lux)
Transmissivity Glass = 75 % (PAR)
= Reduction 12 % to Normal Glass

Globalradiation(300 – 3.000 nm)
Reduction 40% to Control-House

Strong Transmissivity-Loss in IR-Range
= lower Heat Load during Day

Transmissivity Construction:
Control-House 54 % (Reduction by 46 %)
WS- Glass 45 % (Reduction by 55%)

Quelle: J. Mayer, TUM, 2013

Osnabrück: Heat-Protection-Glass

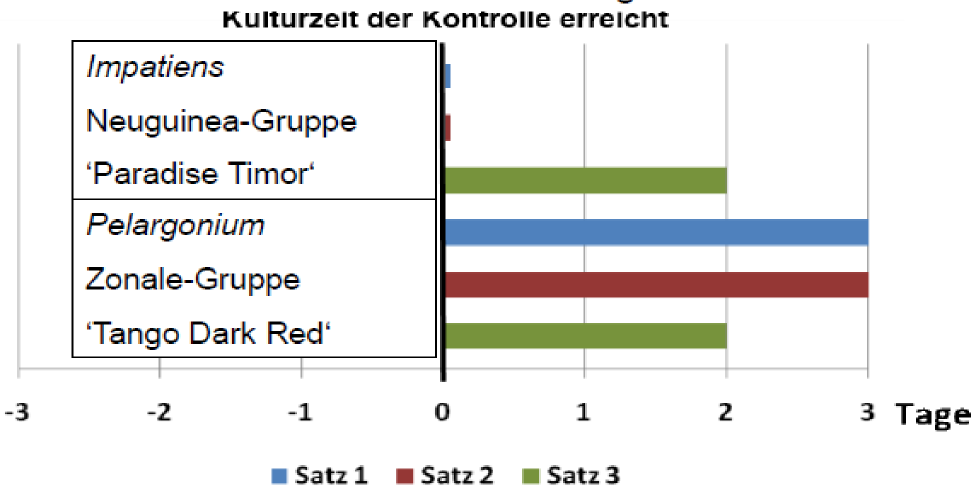
Pflanzenwachstum

Relative Kulturdauer von Impatiens und Pelargonien unter Einfach- und Wärmeschutzglas (Kulturdauer: Tage bis 60 % der Pflanzen verkaufsreif)

Hochschule Osnabrück
University of Applied Sciences

Tage Kulturdauer unter Wärmeschutzglas

kürzer länger als Kontrolle



| Römer | ZINEG Osnabrückl | KTBL2012 | 19

Results Osnabrück Plant-Production

- Higher Air Humidity under WS- Glass = lower Transpiration
- No Botrytis- Infestation
- No big Differences (max. 10 %) in : Hight, Diameter, Plant-Weight, Plant-Quality, Harvest-Date

Quelle: J. Mayer, TUM, 2013

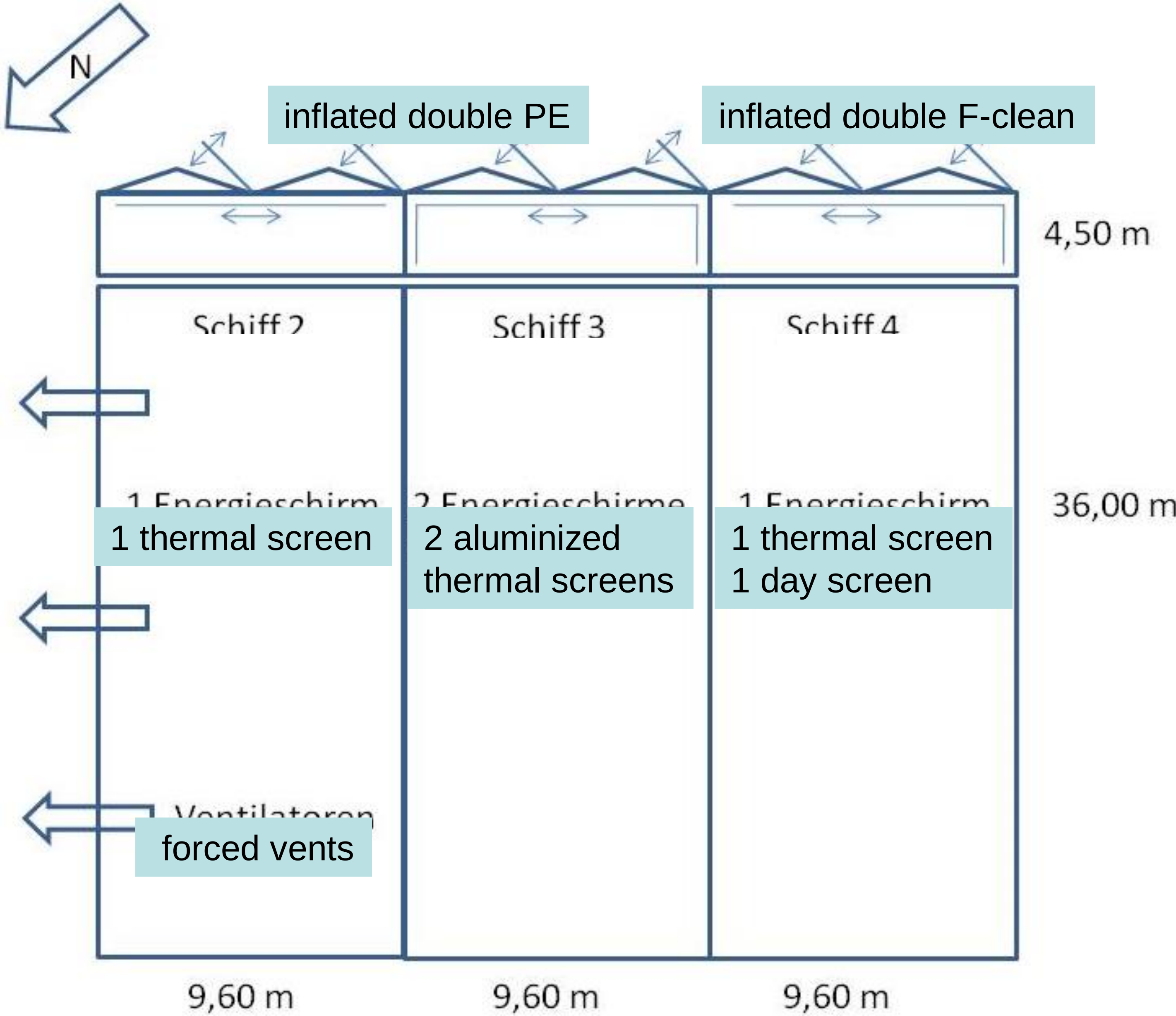
outlay and aims of the experiment greenhouse

lighthouse project  **to show the right direction**

- **greenhouse for organic vegetable production**
- **optimized film plastic construction**
- **very good insulation**
- **non fossil heating system and**
- **automatic monitoring of the production processes and**
- **calculation of a product specific carbon footprint**

Quelle: J. Mayer, TUM, 2015

Quelle: J. Mayer, TUM, 2015



Quelle: J. Mayer, TUM, 2015

Compartment 1 with inflated double PE roof and one thermal screen

.

Quelle: J. Mayer, TUM, 2015

Compartment 2 with inflated double PE roof and two IR reflective thermal screens

.

Quelle: J. Mayer, TUM, 2015

Compartment 3 with inflated double F-clean roof and one thermal screen plus one day-time screen

.

Quelle: J. Mayer, TUM, 2015

Attention to the wide opening ventilators

.

Quelle: J. Mayer, TUM, 2015

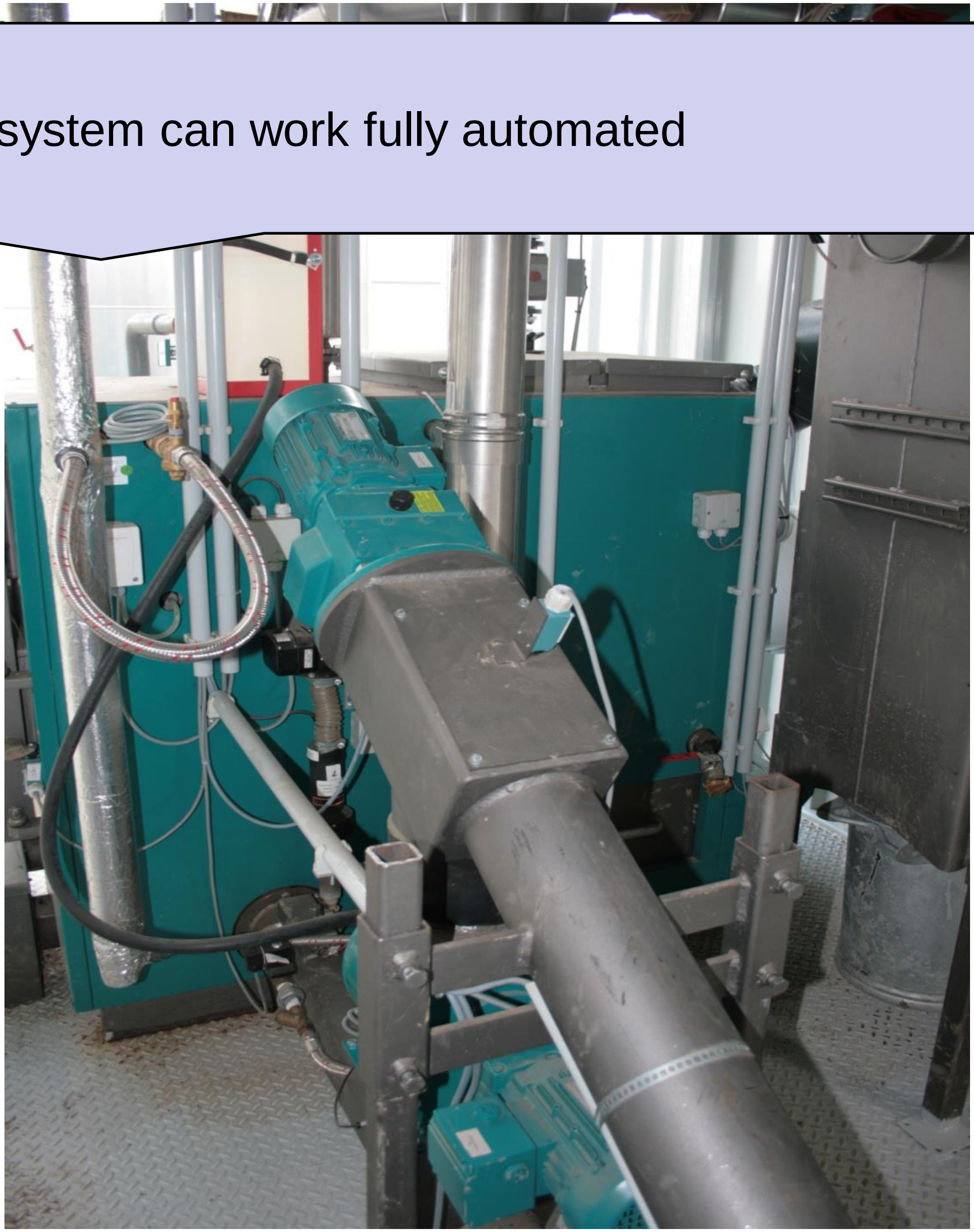
Container with wood pellet burner and –storage and heat storage

Quelle: J. Mayer, TUM, 2015

By means of the heat storage heat procuction and heat consumption can be separated. This leads to an instant heat availlability and to a better burner efficiency when the storage is loaded

Quelle: J. Mayer, TUM, 2015

The burner system can work fully automated



Quelle: J. Mayer, TUM, 2015

additional equippment

<u>Climate control computer for</u>

optimized climate control and spec.

avoiding humidity problems

on-line process documentation and evaluation

<u>adapted heating system for</u>

optimizing leaf temperatures and humidity control

optimizing micro-climate

<u>insect proof ventilation in one greenhouse</u>

reducing infestigation

Quelle: J. Mayer, TUM, 2015

The corrugated heat pipes send long wave radiation particularly to the leaves; this increases leaf temperature and diminishes humidity problems

Quelle: J. Mayer, TUM, 2015

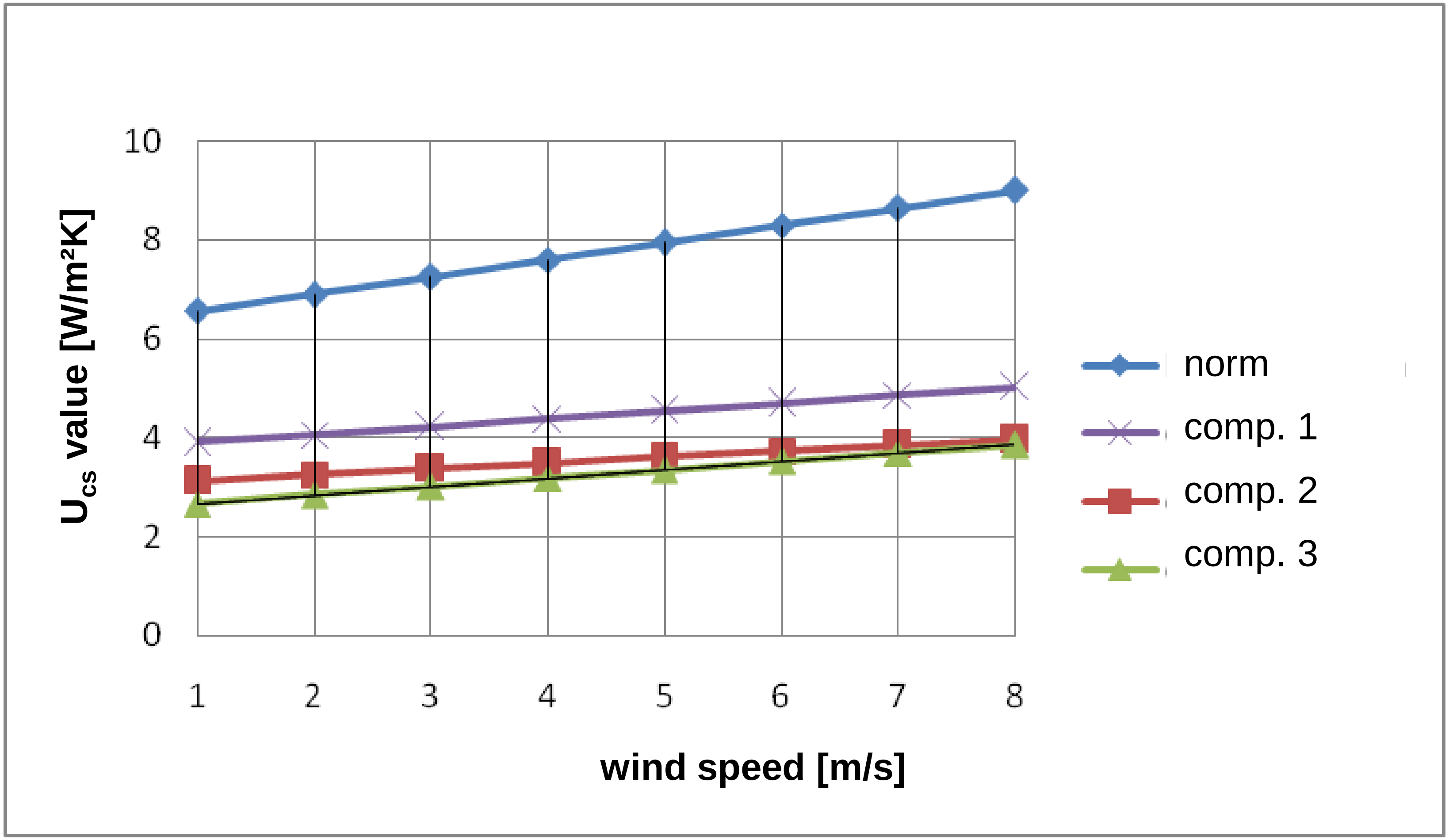
Energy Consumption Coefficient “U_{cs}”

The amount of energy that is transported through one square meter of greenhouse surface, at a temperature difference of 1K (1°C), between inside and outside temperature.

Energy Consumption Coefficient “U_{cs}” of a non insulated greenhouse is around 7,6 W/m^2 K

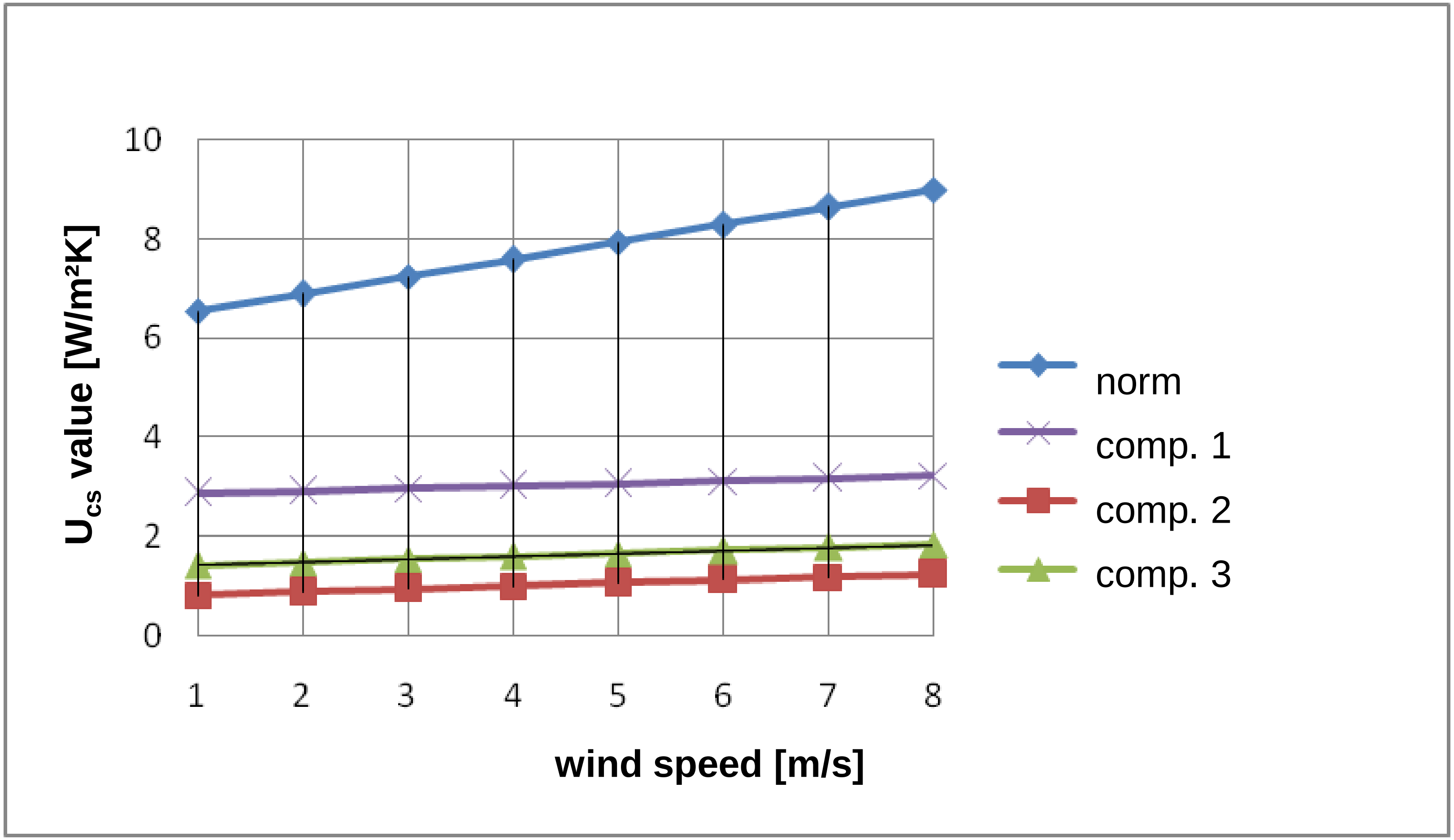
Quelle: J. Mayer, TUM, 2015

thermal screens open



Quelle: J. Mayer, TUM, 2015

thermal screens closed



Quelle: J. Mayer, TUM, 2015

Results of the measurements of the heat consumption coefficient

	Compartment 1	Compartment 2	Compartment 3	Reference single glass
	U‵-value at a wind speed of 4 m/s	U‵-value at a wind speed of 4 m/s	U‵-value at a wind speed of 4 m/s	U‵-value at a wind speed of 4 m/s
Open thermal screens	4,3	4,6	3,1	7,6
Closed thermal screens	2,9	0,9	1,4	
Energy-saving with screens	~60%	~90%	~80%	Compared to the reference 7,6

Quelle: J. Mayer, TUM, 2015

conclusions to the topic of energy saving

The energy saving capacities are really encouraging

The technical system proved its reliabilty convincing

Thus the technical prerequisits are given but is this already the energy efficiency we are aiming at???

Quelle: J. Mayer, TUM, 2015

conclusions to the topic of energy saving

The energy saving capacities are really encouraging

The technical system proved its reliabilty convincing

Thus the technical prerequisits are given but is this already the energy efficiency we are aiming at???

No!!!!

There are at least three points missing!

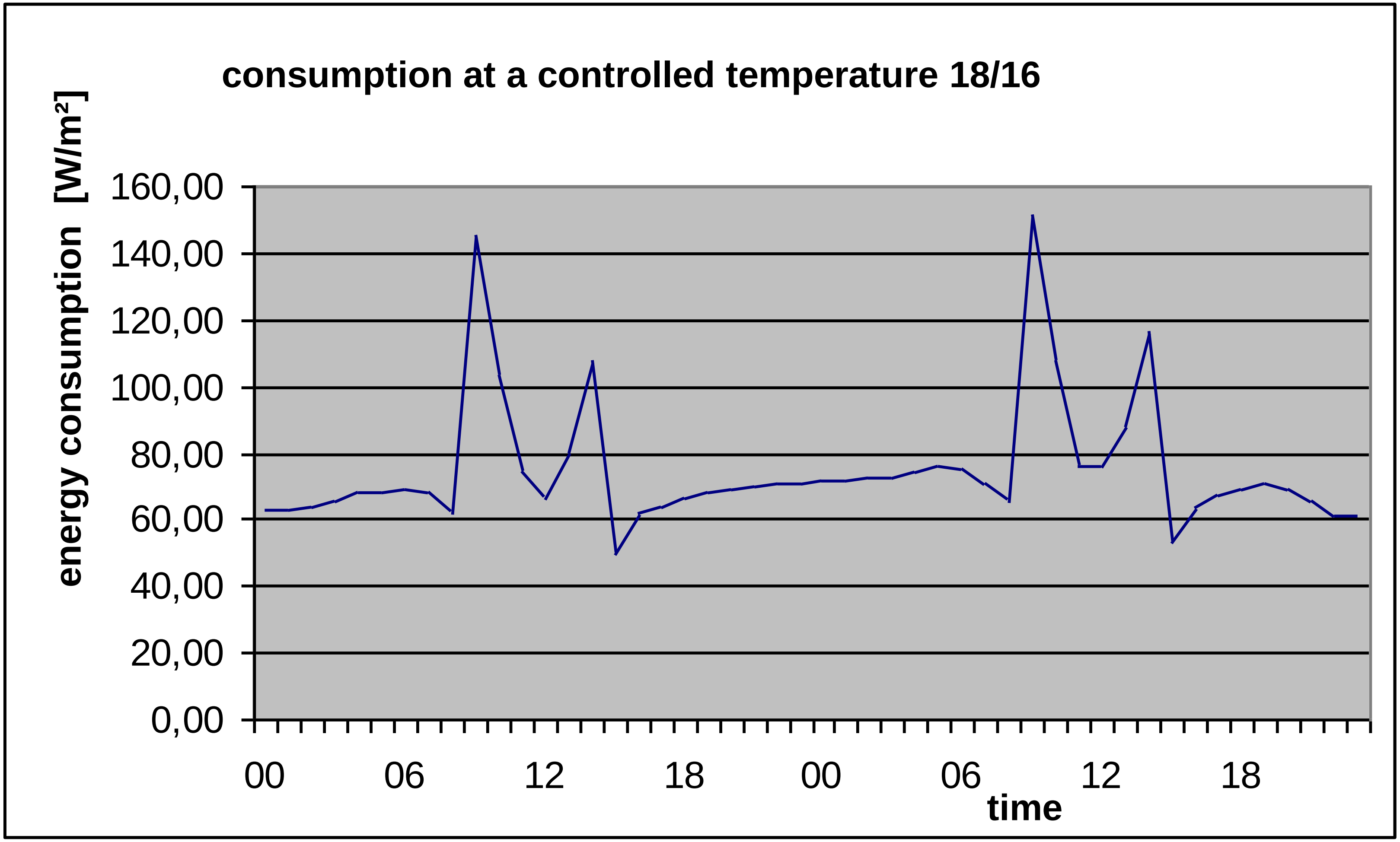
Quelle: J. Mayer, TUM, 2015

For a given technical system the true energy saving is mainly influenced by the knowlegde of the grower

- **During a production period the saving is influenced mainly by the temperature control strategy**
- **During a production period the saving is influenced mainly by the humidity control strategy**
- **And the energy efficiency is moreover mainly influenced by the cropping results**

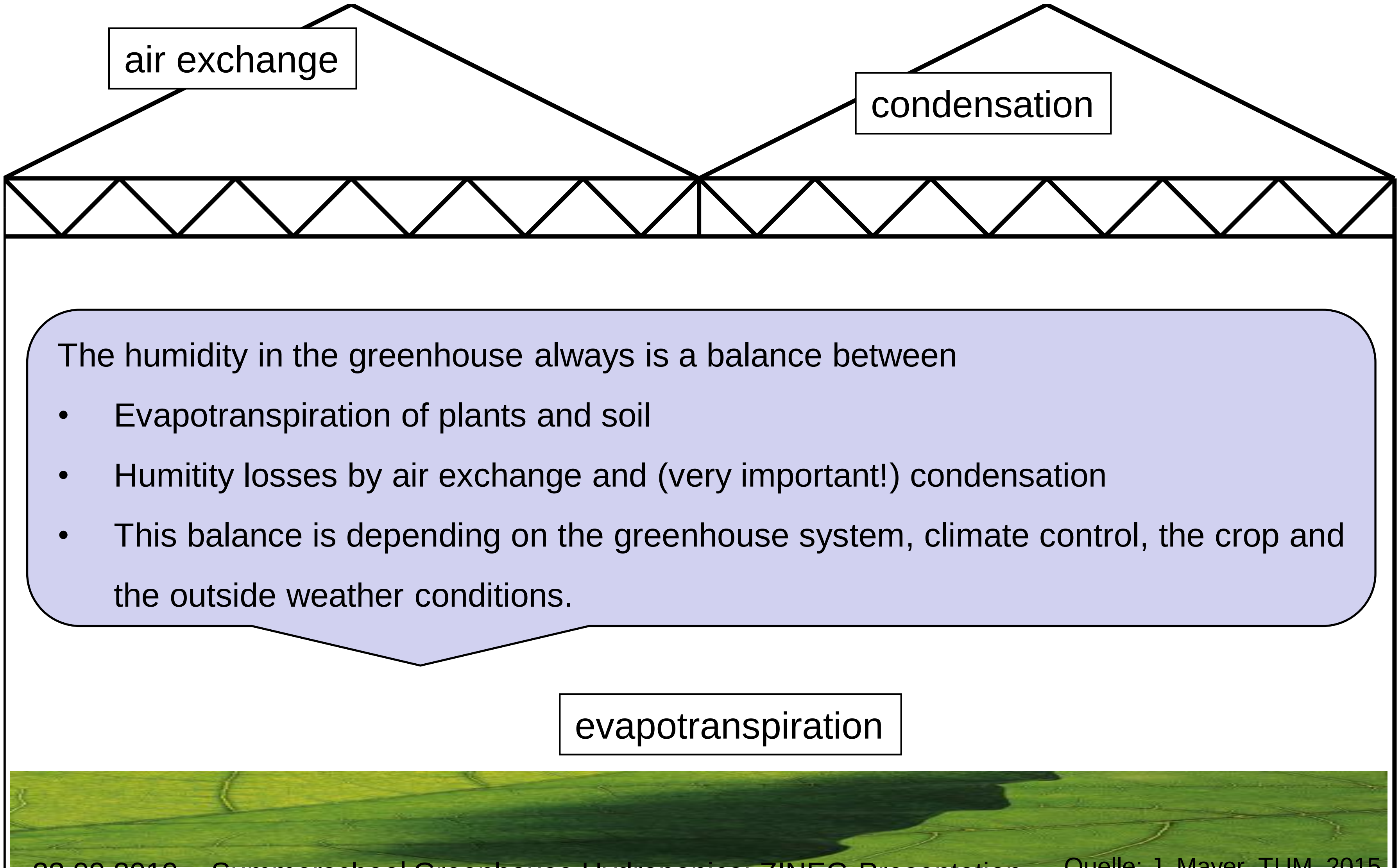
Quelle: J. Mayer, TUM, 2015

calculated daily course of energy consumption in a very good insulated greenhouse



Quelle: J. Mayer, TUM, 2015

The humidity problem



The humidity in the greenhouse always is a balance between

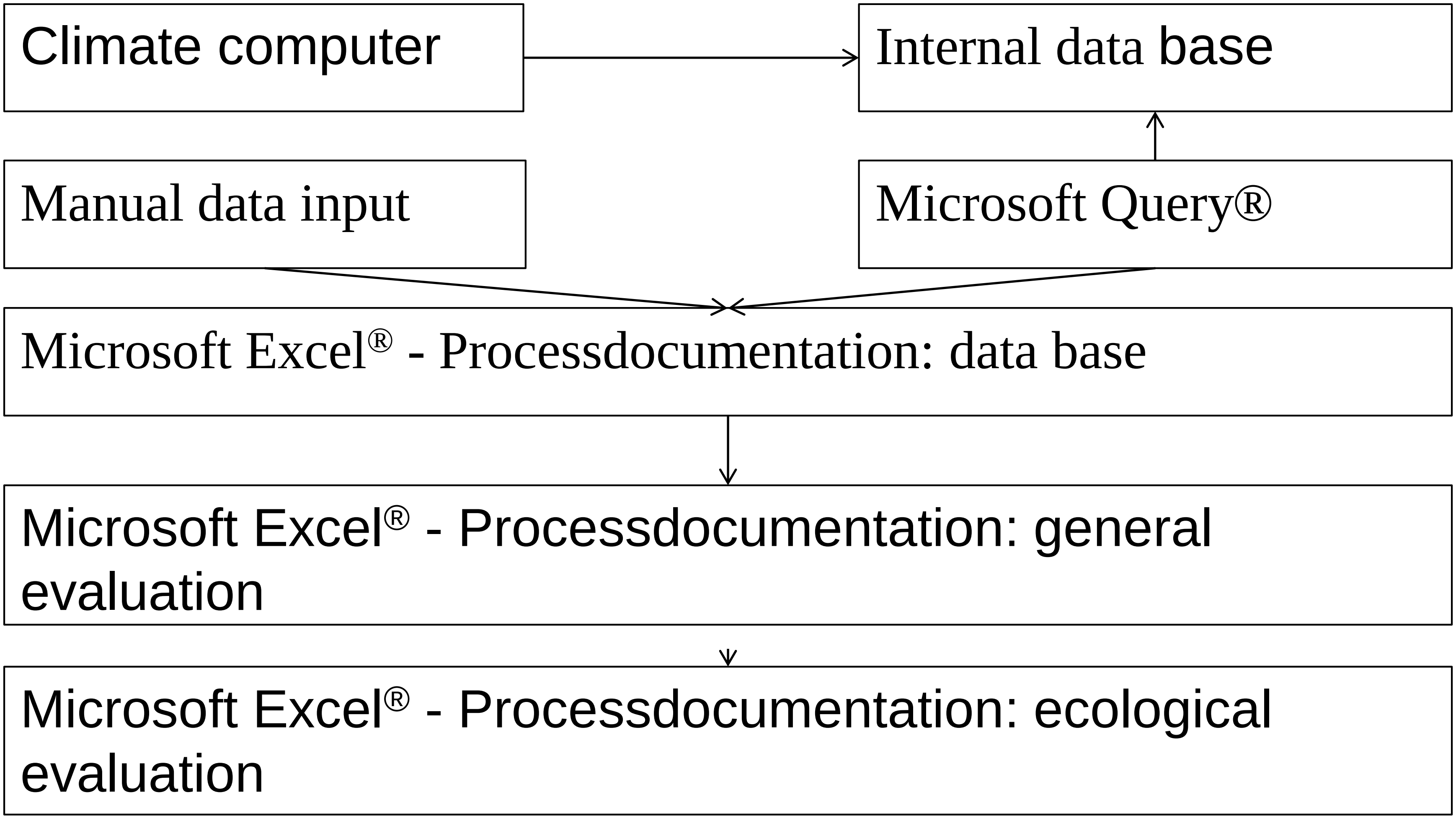
- Evapotranspiration of plants and soil
- Humitity losses by air exchange and (very important!) condensation
- This balance is depending on the greenhouse system, climate control, the crop and the outside weather conditions.

Quelle: J. Mayer, TUM, 2015

The humidity problem

Quelle: J. Mayer, TUM, 2015

Processdocumentation – data transfer and converting



Quelle: J. Mayer, TUM, 2015

Tomato Production 2012

- Greenhouse size of every section 346 m^2
- Production area 104 m^2
- Production time 22.02. - 29.11.2012

Entire harvest (kg)			
	Section 1	Section 2	Section 3
Entire harvest	5100	4140	6155

Quelle: J. Mayer, TUM, 2015

Processdocumentation „Tomate 2012"

- use of heating material in kg (wood pellets)

Functional unit	Greenhouse section 1	Greenhouse section 2	Greenhouse section 3
Entire consumption	8900	5800	5000
Consumption/m^2	25	16	14
Consumption/kg	2,1	1,3	0,8

Quelle: J. Mayer, TUM, 2015

Results for the practical grower

Heated film plastic greenhouses should be equipped with inflated double roofs.

Multi-layer thermal screens are a most interesting investment (which screen are chosen depends on heat and shading demand of the crop)

Radiant heating systems in the crop area improve humidity conditions considerably

Good control equippment is absolutely necessary

Passive solar energy use can be optimized by temperature integration

Heat supply by alternaive energy resources as much as possible

To avoid humidity problems most attention should be given to the humidity sources e.g. unnessecery evaporation, irrigation at the wrong time .

Quelle: J. Mayer, TUM, 2015

improved screens in greenhouse 2

Quelle: J. Mayer, TUM, 2015

improved screens in greenhouse 3

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ZINEG

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  Thank You for Your Attention

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rentenbank

Quelle: J. Mayer, TUM, 2015