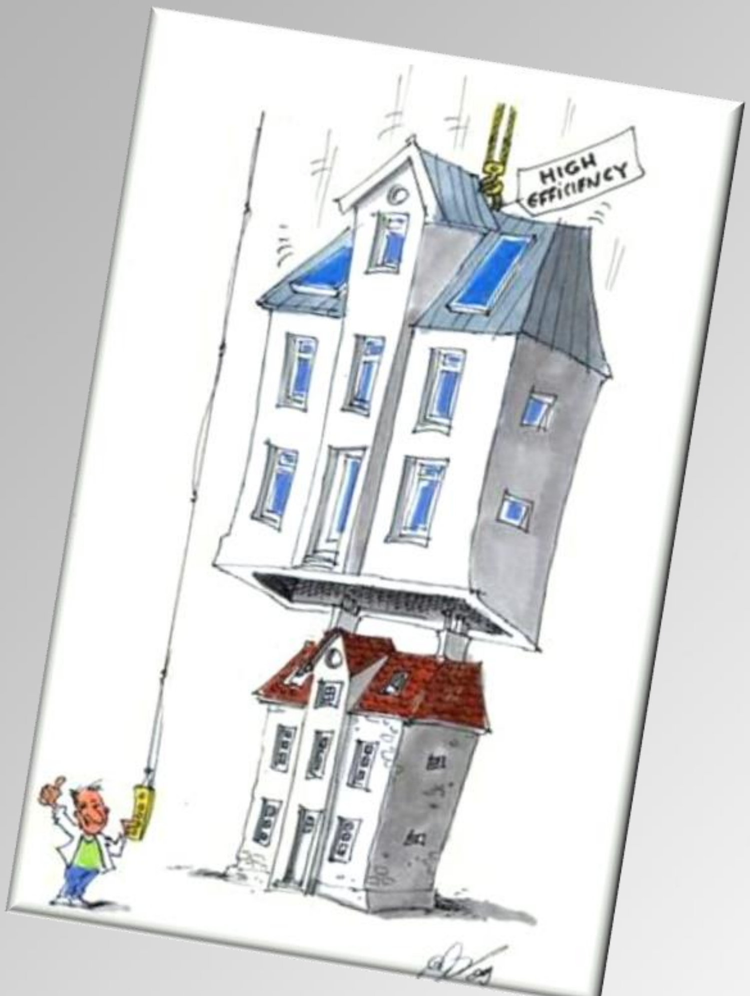


NEW CHALLENGES FOR THE BUILDING ENERGY EFFICIENCY IN BULGARIA – SOME RESULTS OF TWO R&D PROJECTS AT THE TECHNICAL UNIVERSITY-SOFIA

Prof.Dr. Nikola Kaloyanov

Two research projects funded by the National Fund for Scientific Research at the Ministry of Education and Science of Bulgaria:

DUNK-01/3 "Creating an University Research and Development Centre for innovation and transfer of knowledge in the field of micro/ nano technologies and materials, energy efficiency and virtual engineering " in TU-Sofia-with partners: *the Technical University of Sofia, the University of Chemical Industry and Metallurgy - Sofia, and the Bulgarian Academy of Science.*

DFNI E 02/17" Parametric analysis for evaluation of the efficiency of transparent structures in systems for utilization of solar energy - with partners: *the University of Chemical Industry and Metallurgy - Sofia, the Technical University of Sofia and the Technical University Angel Kanchev- Rousse*

SOME of the MAIN TASKS:

1. Thermal properties of materials – experimental study and development of engineering models.

2. Experimental study and structural- parametric optimization of systems for thermal and electrical conversion and utilization of solar energy.

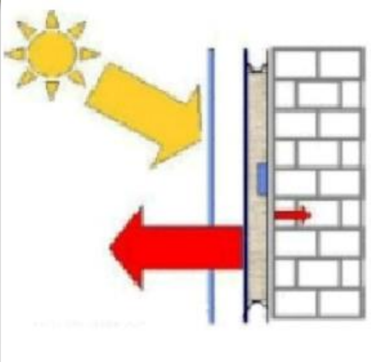
3. Optimization of the energy conversion efficiency in low temperature heat pumps.

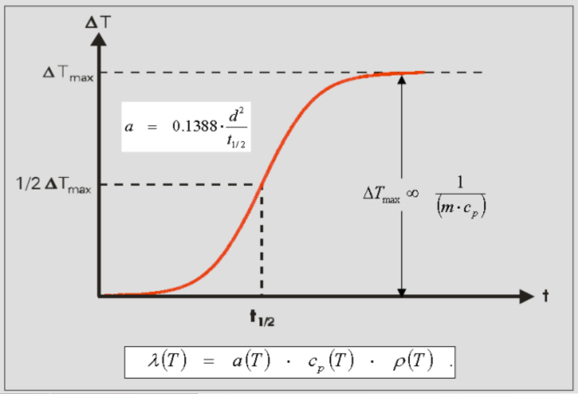
4. Generation of cold by means of solar energy.

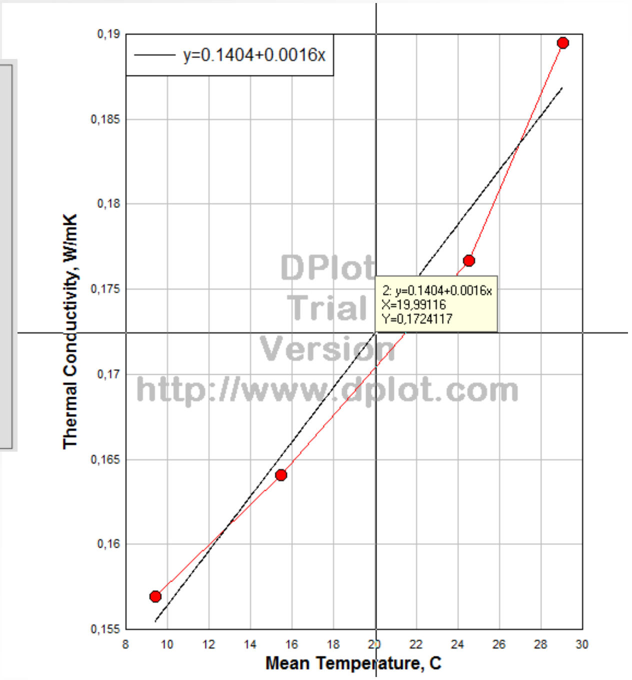
5. Energy performance of buildings – models for evaluation of building annual energy consumption, experimental study of different applications of passive building elements,…

NEW LABORATORY "THERMAL PROPERTIES OF MATERIALS"

1. Thermal properties of materials

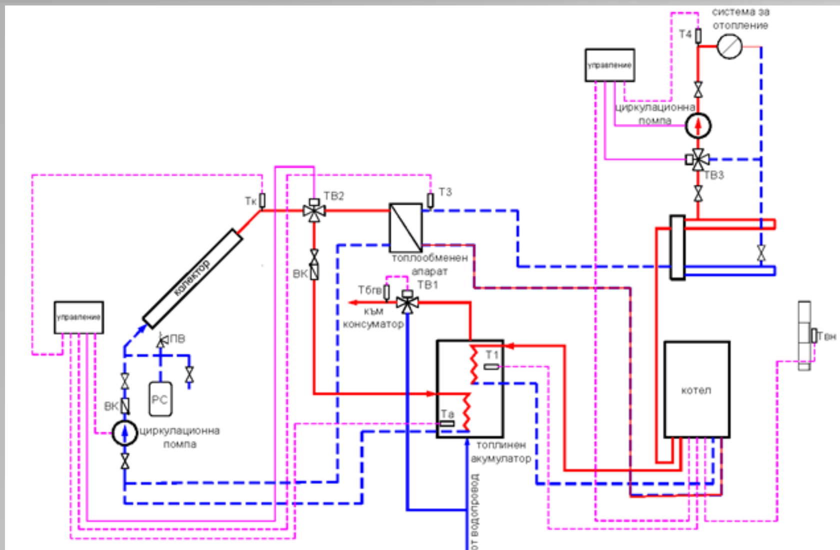


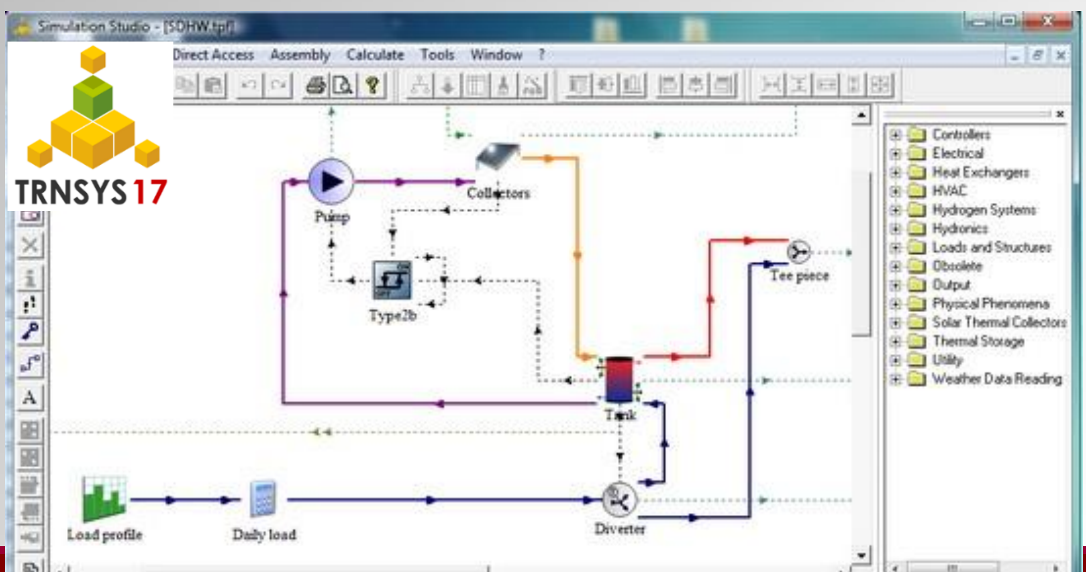


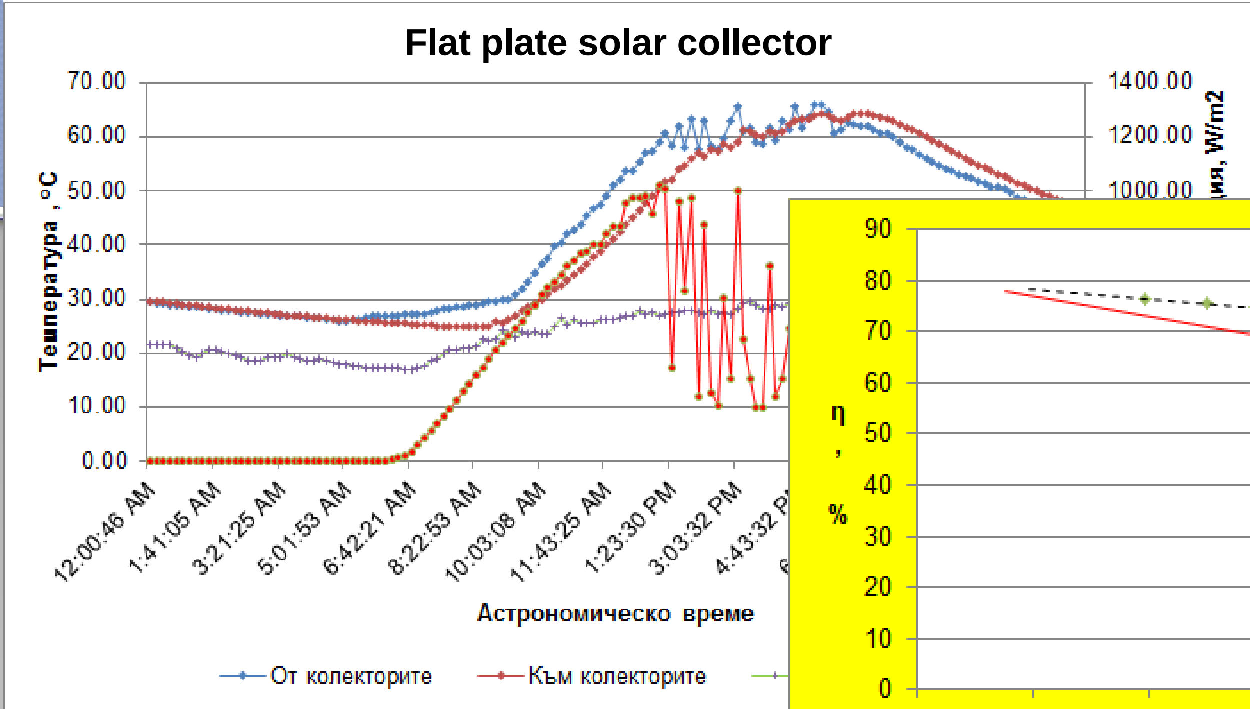


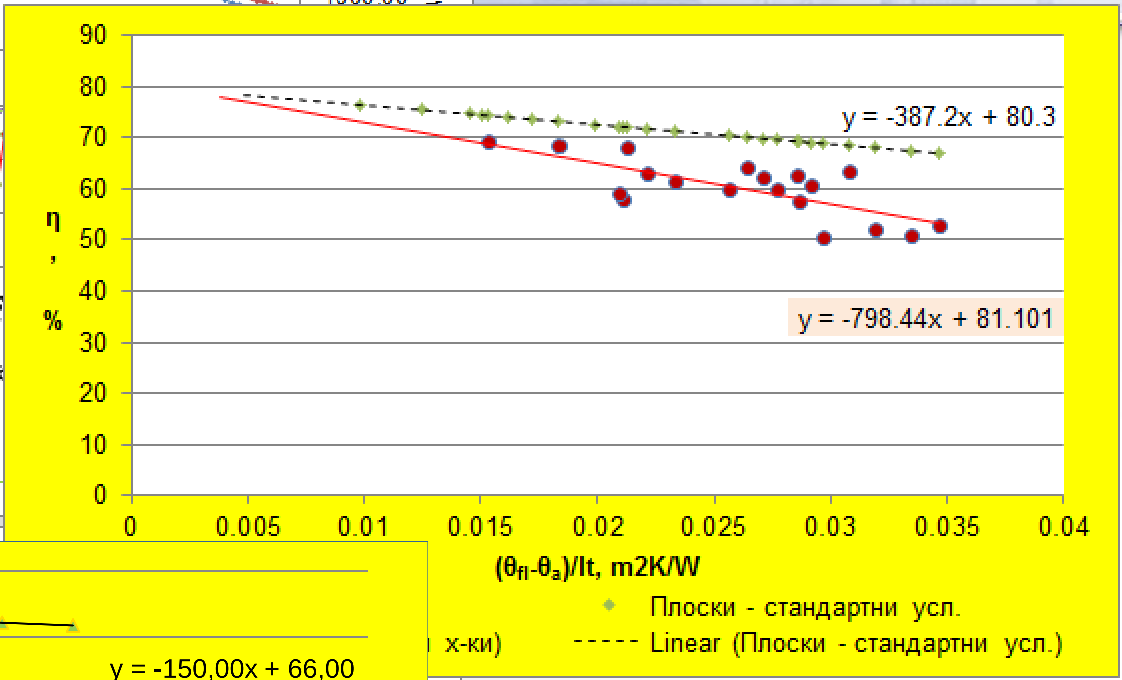
$$\varepsilon = \frac{\lambda_{декл} - \lambda_{изм}}{\lambda_{изм}} .100 = \frac{0{,}13 - 0{,}1724}{0{,}1724} .100 = -24{,}55\%$$

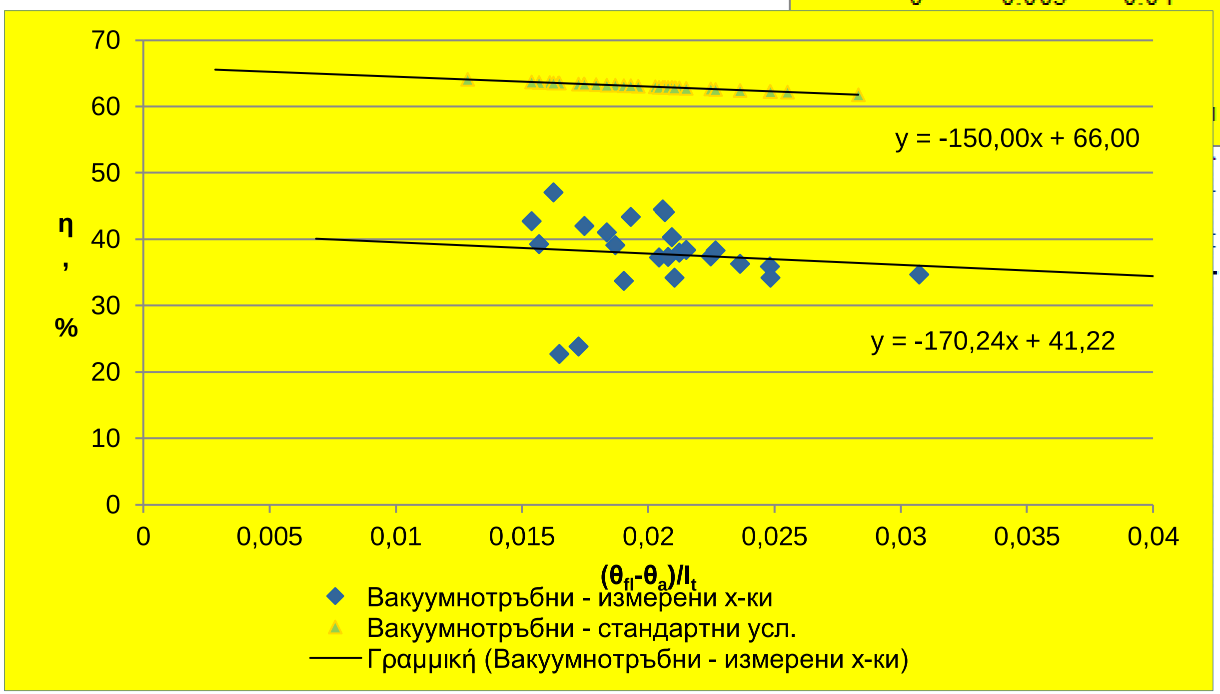
2. Experimental study and structural-parametric optimization of systems for thermal and electrical conversion and utilization of solar energy



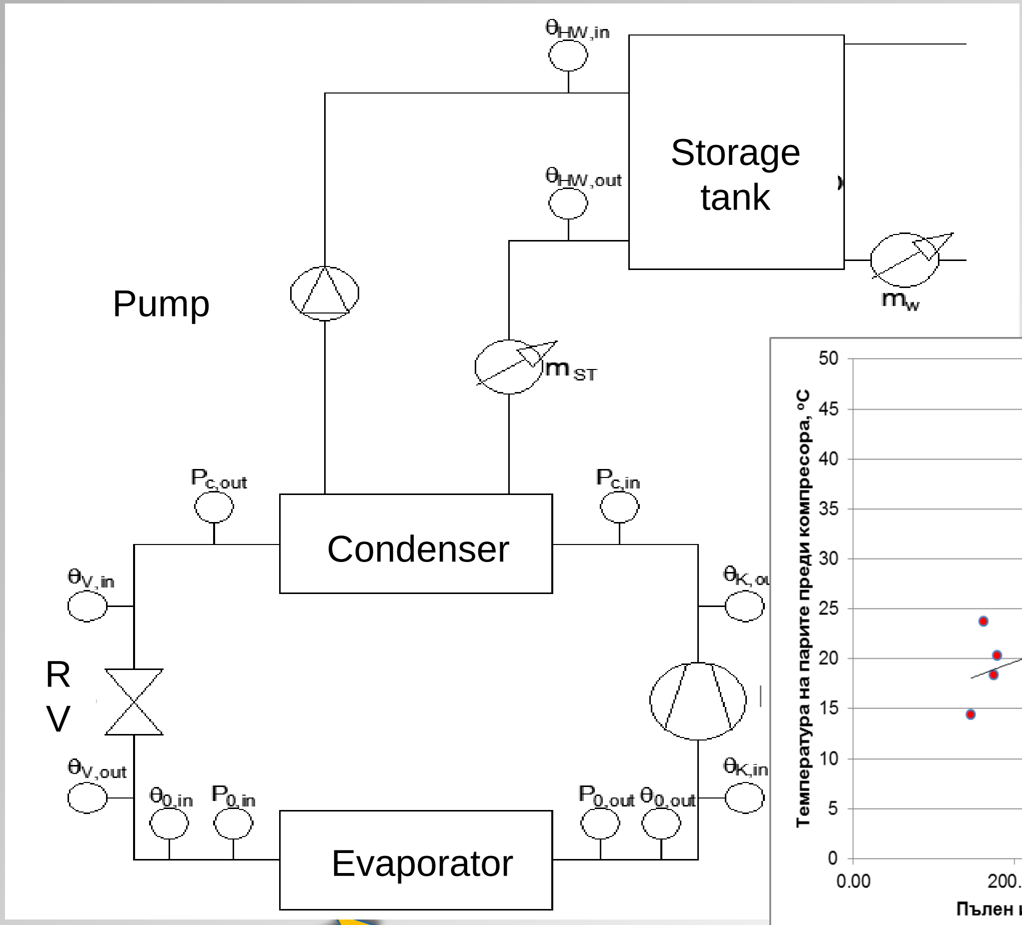


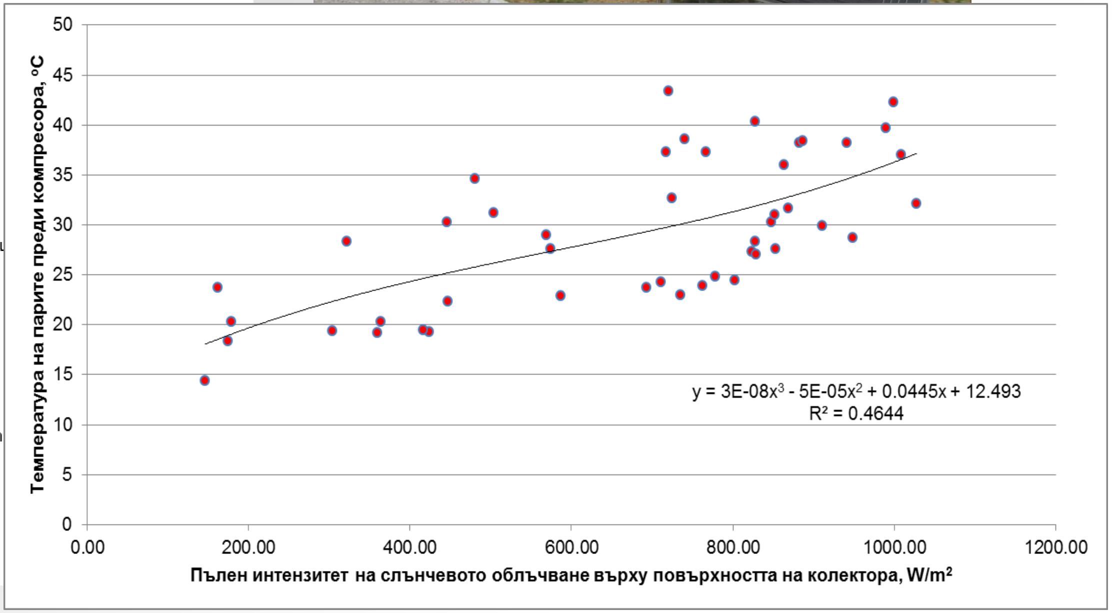

Flat plate solar collector
Температура , °C
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1400.00
1200.00
1000.00
12:00:46 AM
1:41:05 AM
3:21:25 AM
5:01:53 AM
6:42:21 AM
8:22:53 AM
10:03:08 AM
11:43:25 AM
1:23:30 PM
3:03:32 PM
Астрономическо време
От колекторите
Към колекторите


η , %
90
80
70
60
50
40
30
20
10
0
y = -387.2x + 80.3
y = -798.44x + 81.101
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
$(\theta_{fl}-\theta_a)/It$, m2K/W
Плоски - стандартни усл.
х-ки)
Linear (Плоски - стандартни усл.)

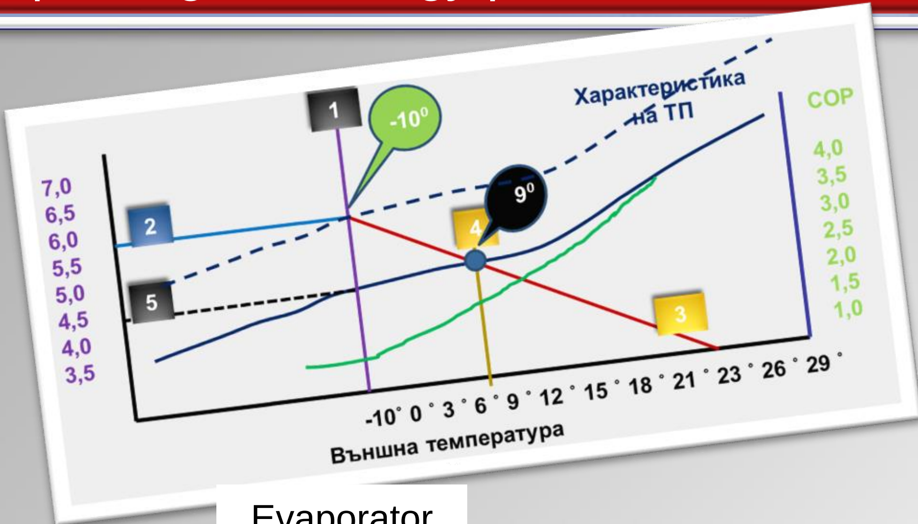

η , %
70
60
50
40
30
20
10
0
y = -150,00x + 66,00
y = -170,24x + 41,22
0
0,005
0,01
0,015
0,02
0,025
0,03
0,035
0,04
$(\theta_{fl}-\theta_a)/I_t$
Вакуумнотръбни - измерени х-ки
Вакуумнотръбни - стандартни усл.
Γραμμική (Вакуумнотръбни - измерени х-ки)

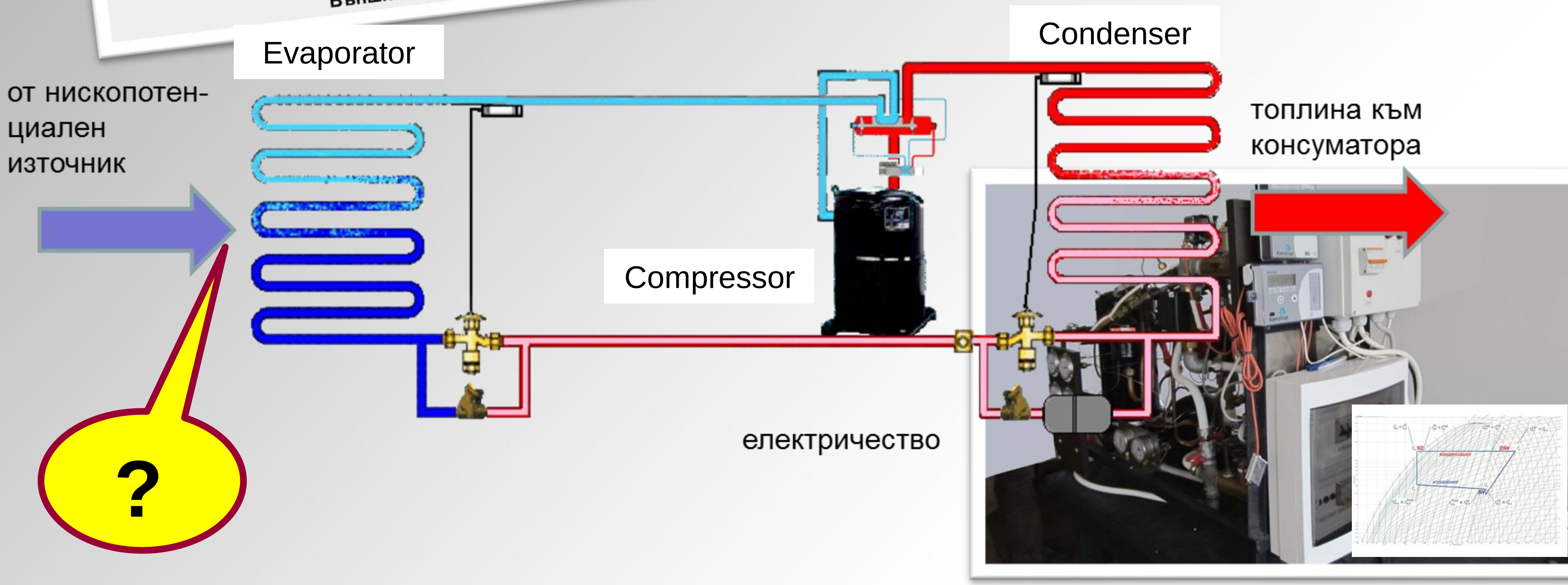
…combined active solar system with radiative solar collector





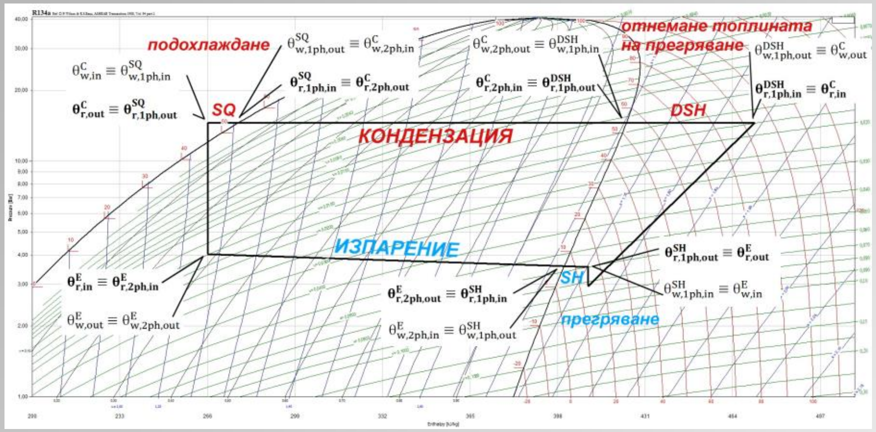
Heat pumps – structural and parametric analysis and synthesis for improving the energy performance of heat pumps

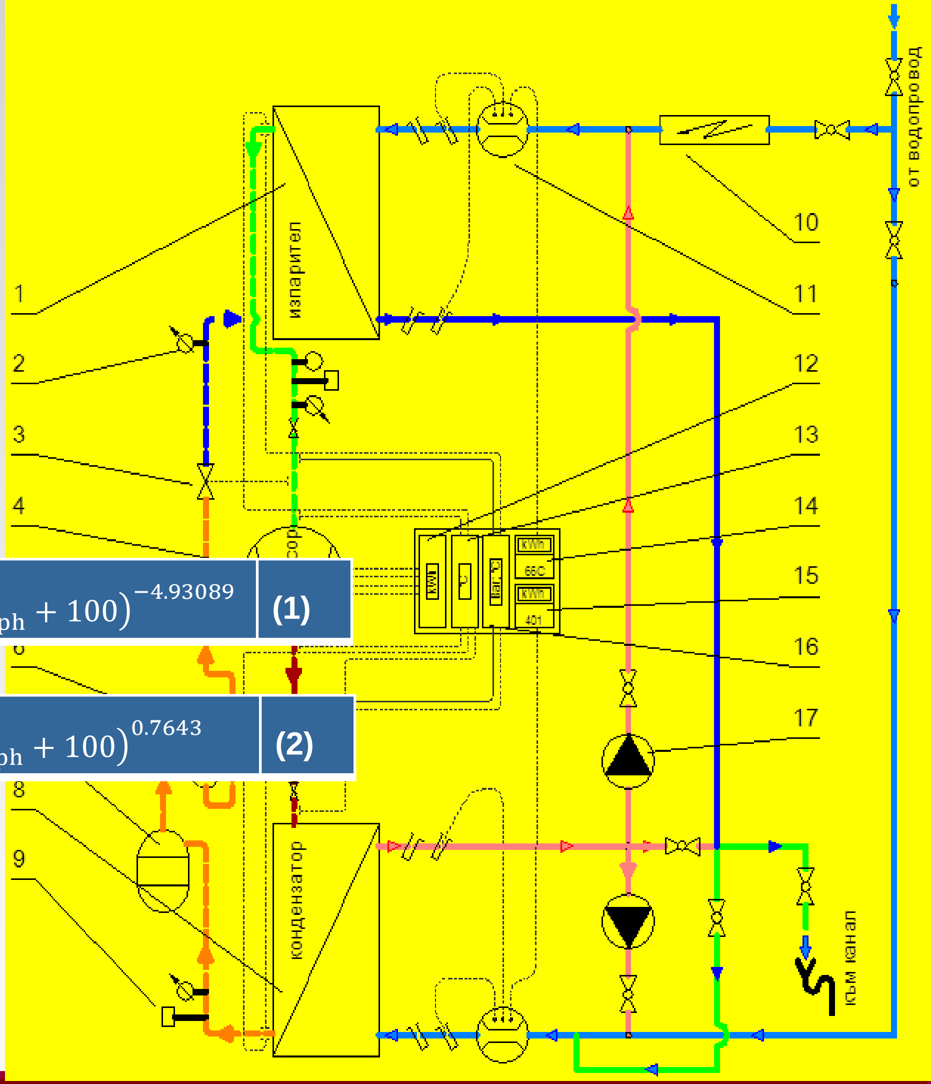




New energy models of the condenser and the evaporator

Фигура 14	Построяване на процес в log P/i диаграма с участъците в едно- и двуфазна област

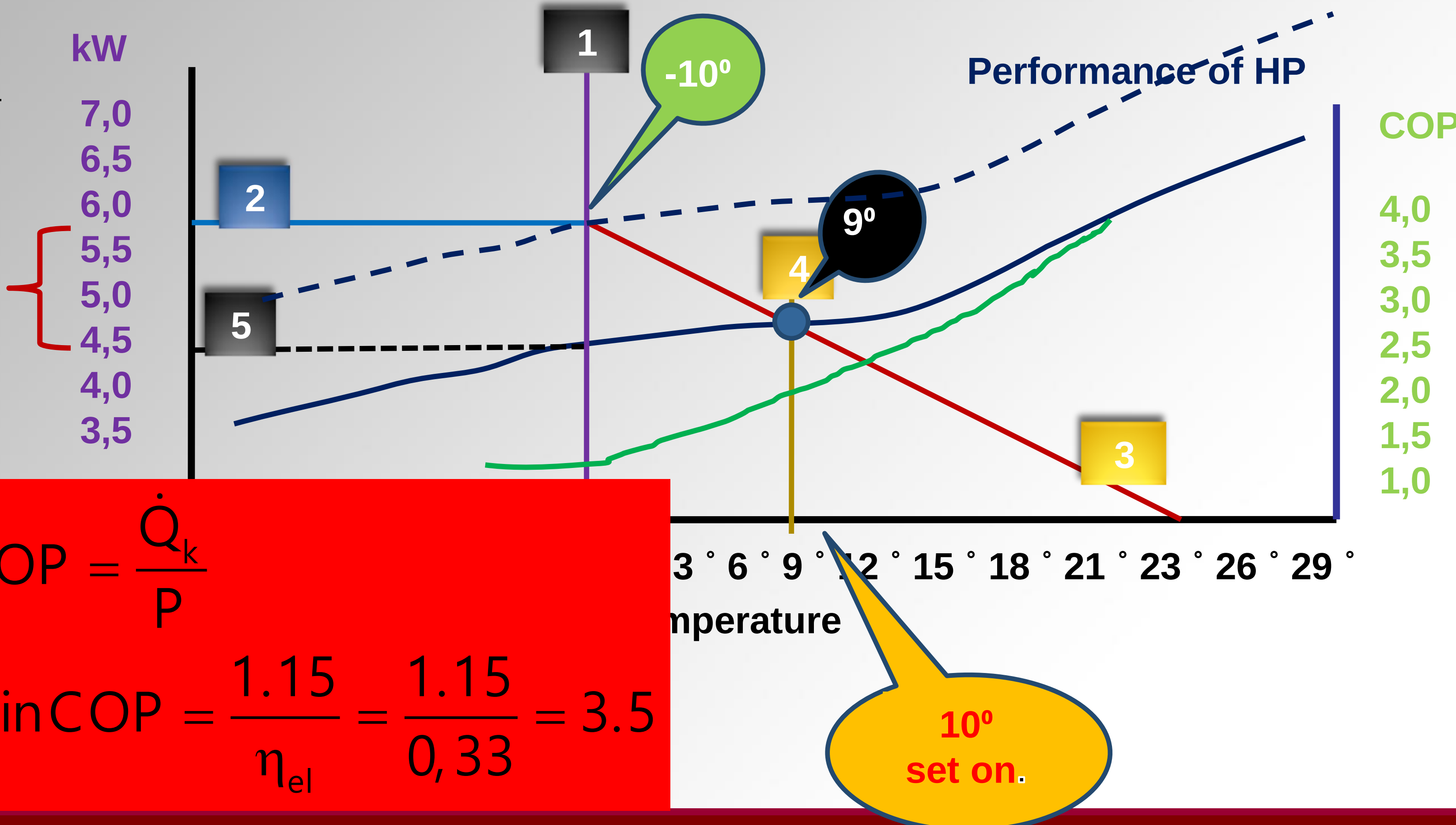




$$U^{C} = 2.04643E+11.\dot{m}_{w}^{C\;0.2058}.\left(\dot{m}_{r}^{C}.100\right)^{0.307}.\theta_{w,1ph,in}^{C\quad 1.5}.\left(\theta_{r,2ph}^{C}+100\right)^{-4.93089} \quad (1)$$

$$U^{E} = 19.133.\dot{m}_{w}^{E\;0.43634}.\left(\dot{m}_{r}^{E}.100\right)^{1.003}.\theta_{w,1ph,in}^{E\quad -0.3425}.\left(\theta_{r,2ph}^{E}+100\right)^{0.7643} \quad (2)$$

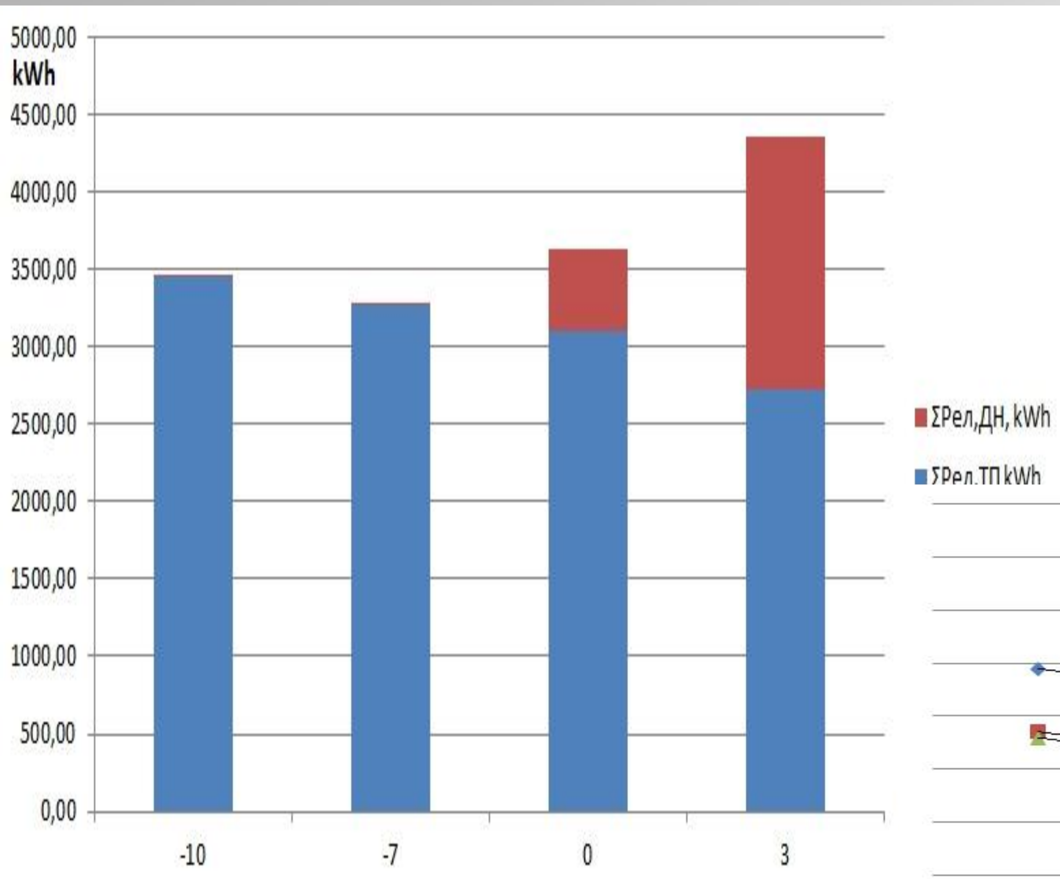
Some our findings about the lack of data for proper application of the heat pumps



$$COP = \frac{\dot{Q}_k}{P}$$

$$\min COP = \frac{1.15}{\eta_{el}} = \frac{1.15}{0,33} = 3.5$$

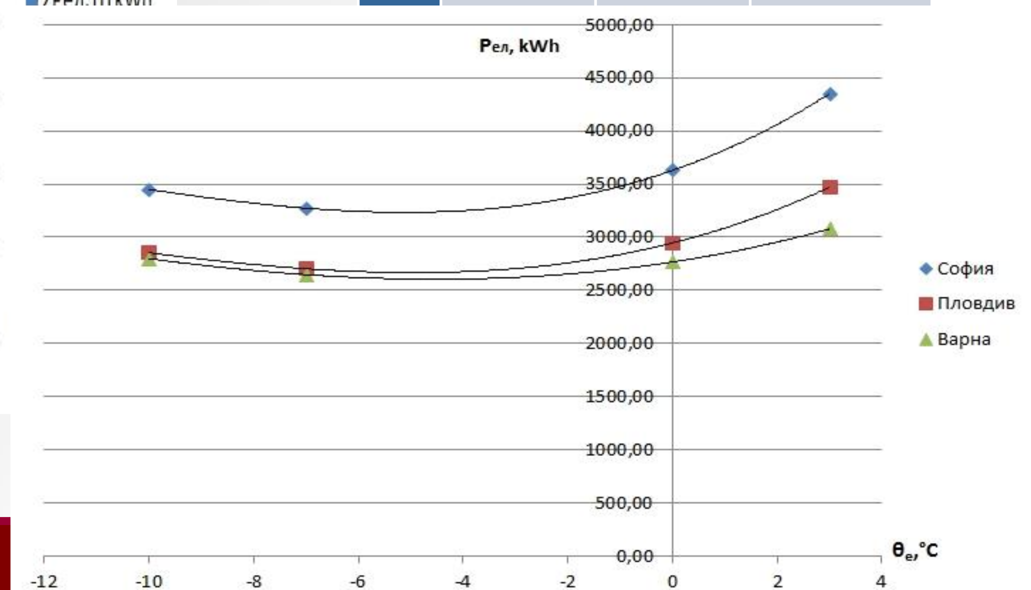
Energy need for heating - residential building in Sofia



Design temperature, °C

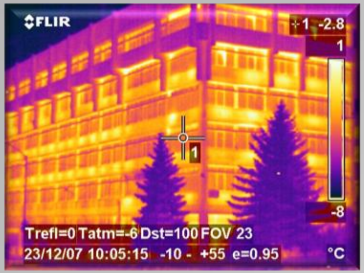
Comparative analysis for different climatic zones in Bulgaria

	София	Пловдив	Варна
	ΣРел, kWh	ΣРел, kWh	ΣРел, kWh
3	4350,04	3470,53	3077,63
0	3628,10	2945,64	2766,33
-7	3272,75	2703,57	2647,41
-10	3449,70	2852,76	2798,47



RESEARCH LABORATORY FOR INFRARED ANALYSES

Development of methods and procedures for application of the infrared analysis for assessment of properties



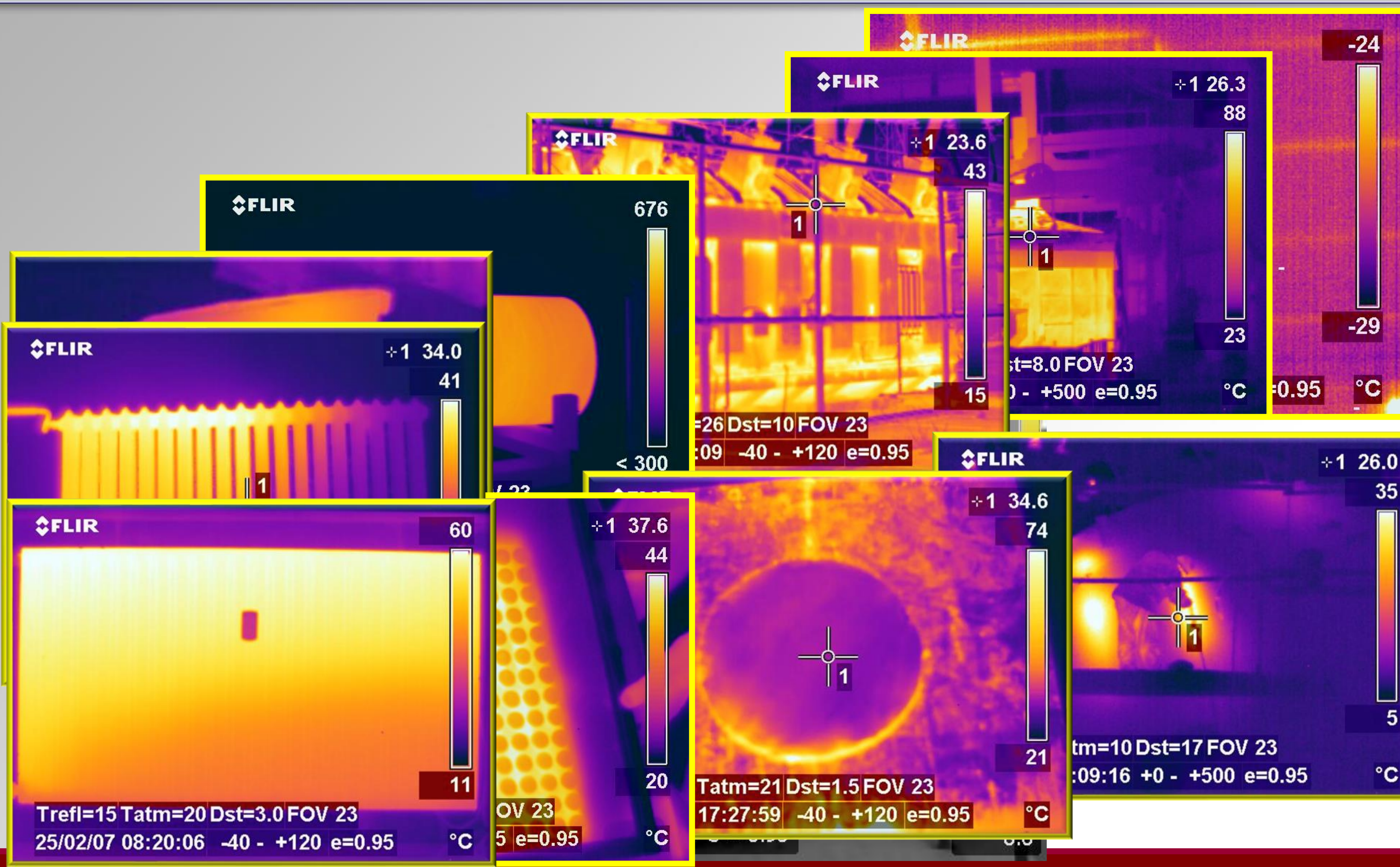
1. Energy efficiency
- *buildings,*
- *HVAC systems*
- *industrial and electrical systems*

2. Diagnostics and preventive control
- *mechanical and electrical systems*
- *quality control*

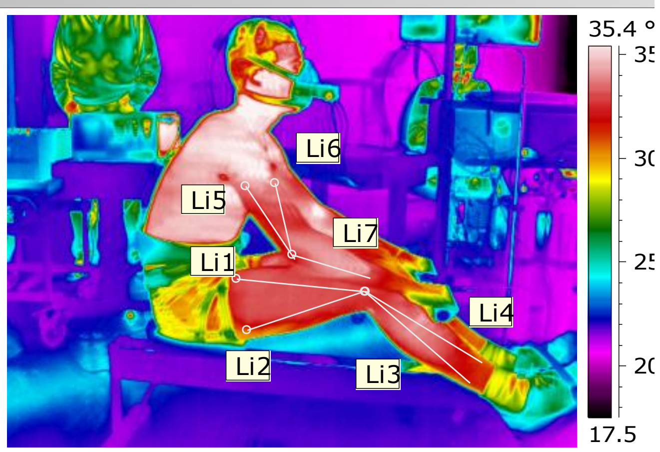
3. New materials
- *identification of properties of new materials*
- *thermal properties of new components*

4. Medicine
- *assessment of medical apparatus for therapy*
- *microclimate*

5. Sport


FLIR
-24
-29
°C
FLIR
1 26.3
88
23
°C
FLIR
1 23.6
43
15
FLIR
676
< 300
FLIR
1 34.0
41
FLIR
60
11
Trefl=15 Tatm=20 Dst=3.0 FOV 23
25/02/07 08:20:06 -40 - +120 e=0.95
°C
1 37.6
44
20
°C
1 34.6
74
21
Tatm=21 Dst=1.5 FOV 23
17:27:59 -40 - +120 e=0.95
°C
FLIR
1 26.0
35
5
°C

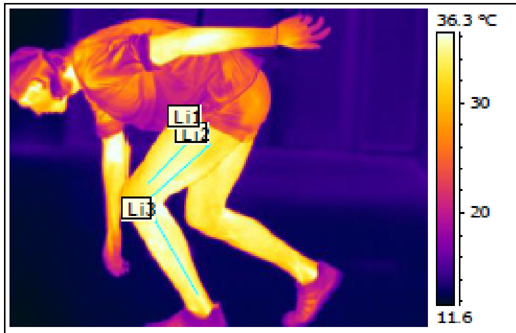
Термограма:гр.1а-7Андрей



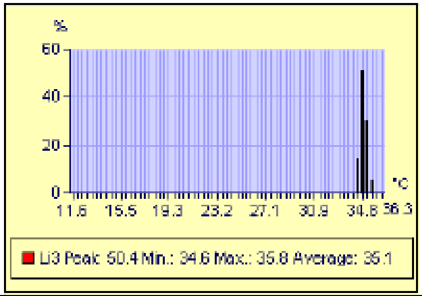
FLIR SYSTEMS	ТЕРМОВИЗИОНЕН АНАЛИЗ	ТЕХНИЧЕСКИ УНИВЕРСИТЕТ СОФИЯ

ОБЕКТ: Атанас

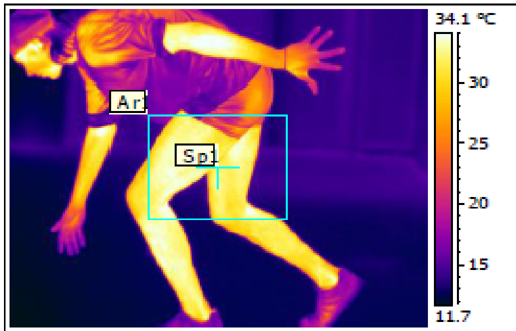
Термограма:Бягане 1



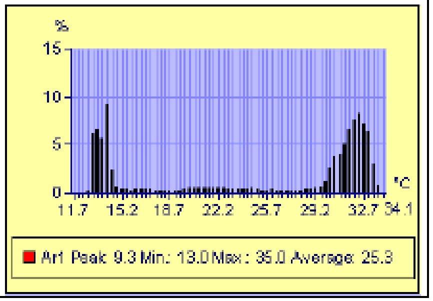
Date	1.12.2011.....
Filename	IR_0238.jpg
Image Time	15:44:49
Emissivity	0.82
Atmospheric Temperature	12.0 °C

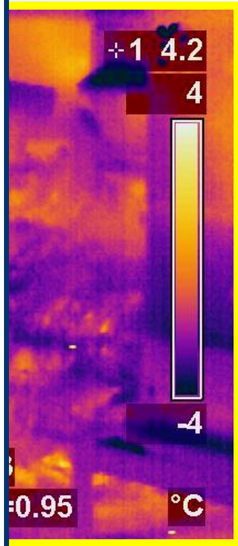


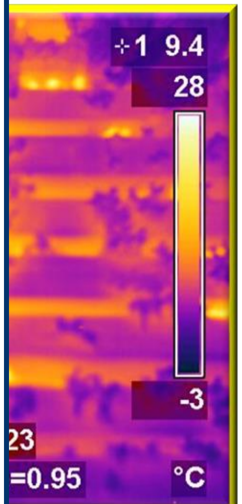
Термограма:Бягане 2



Date	23-12-07
Filename	IR_0904.jpg
Emissivity	0.95
Sp1 Temperature	-3.7 °C
Ar1 Max - Min Temperature	-



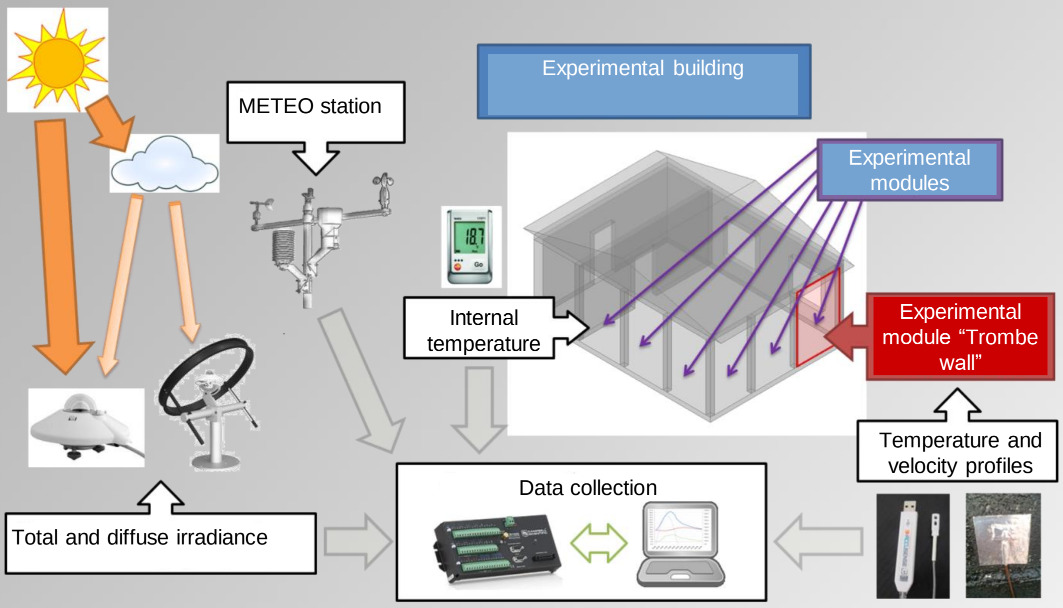


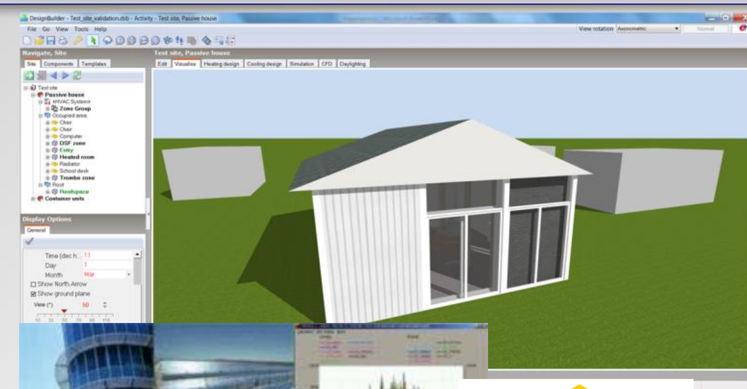


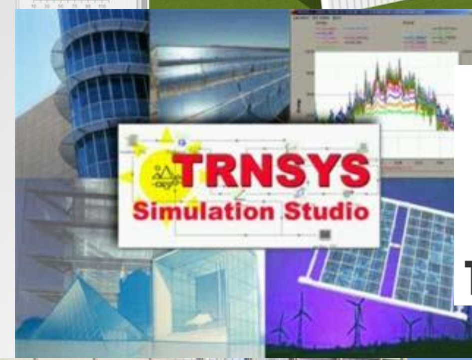
4. Generation of cold by means of solar energy

5. Energy performance of buildings

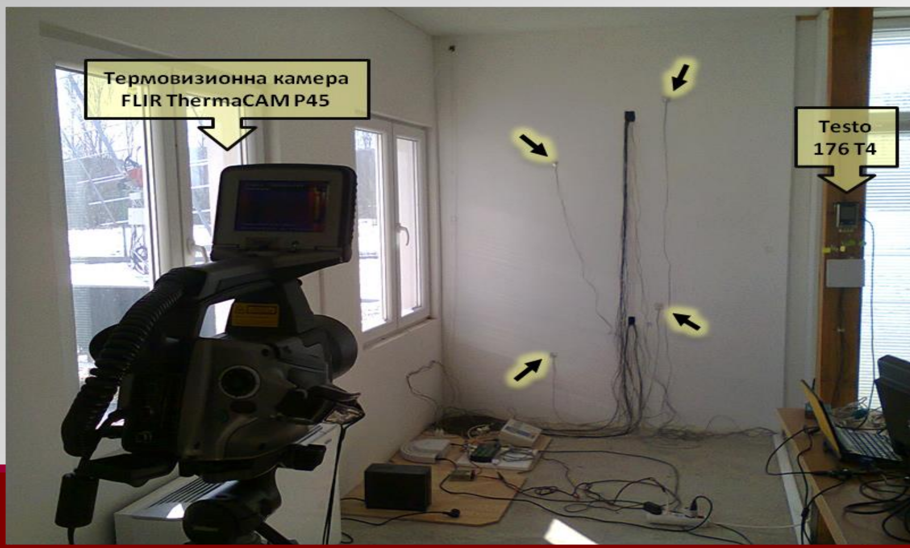
…passive building elements

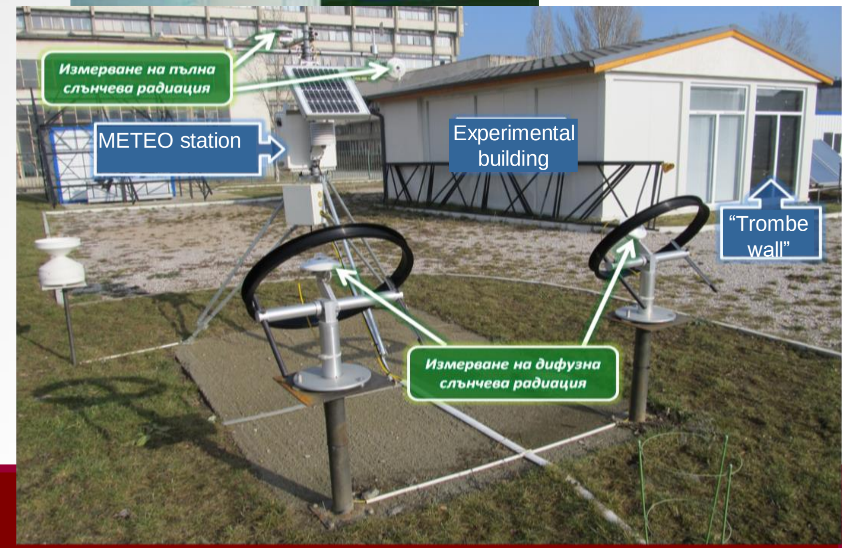




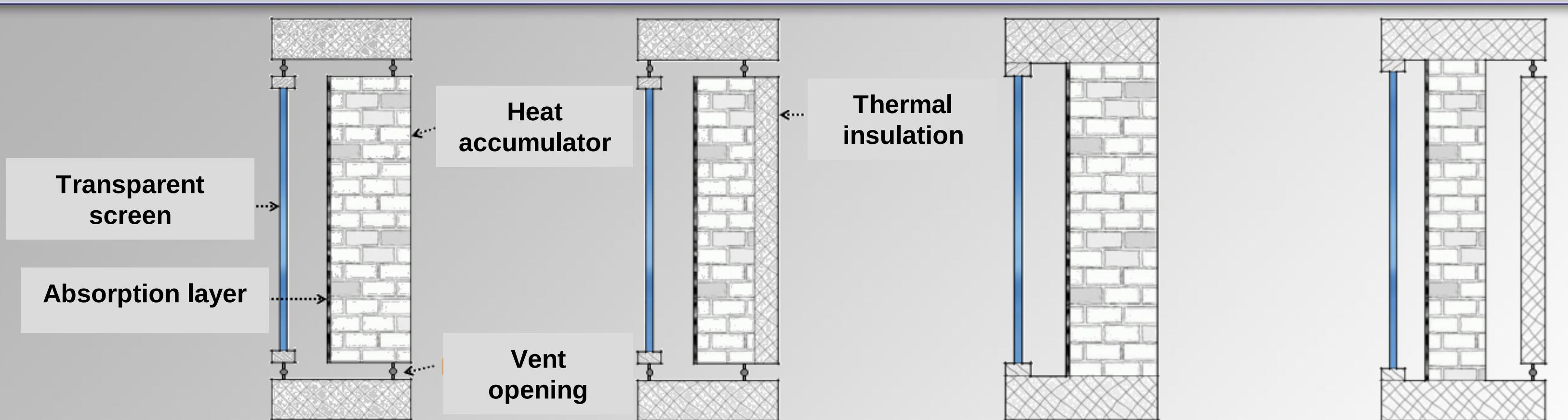


TRNSYS 17





The Trombe wall



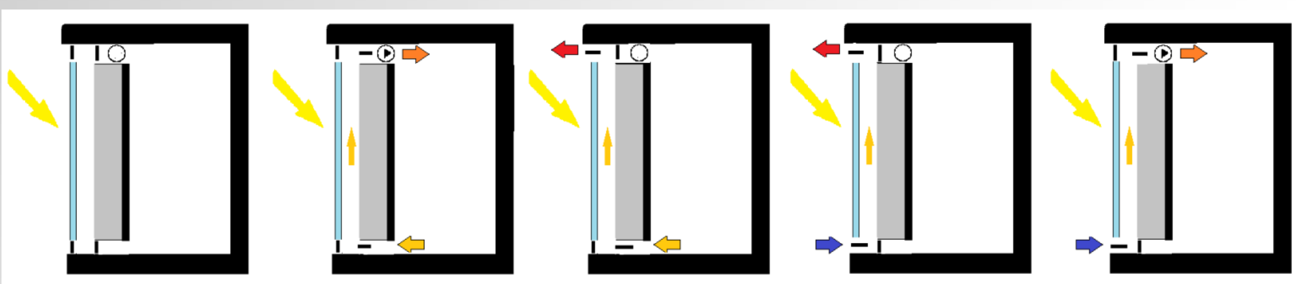
Open Trombe wall

Open Trombe wall with thermal insulation

Closed Trombe wall

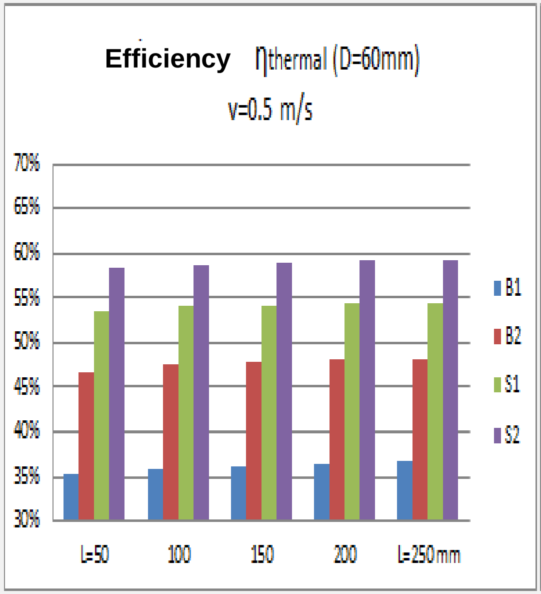
Composite Trombe wall

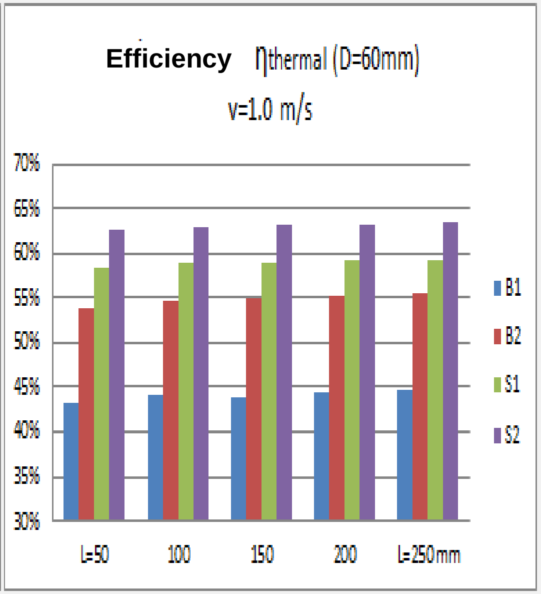
Modes of operation

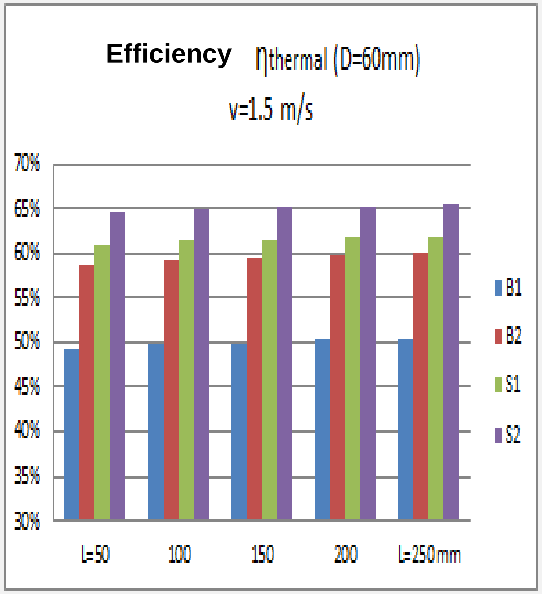


Accumulation of heat	Heating of internal air	Exhaust ventilation	Cooling of the facade	Ventilation of the internal space

The efficiency of the passive elements for the climatic conditions of Bulgaria

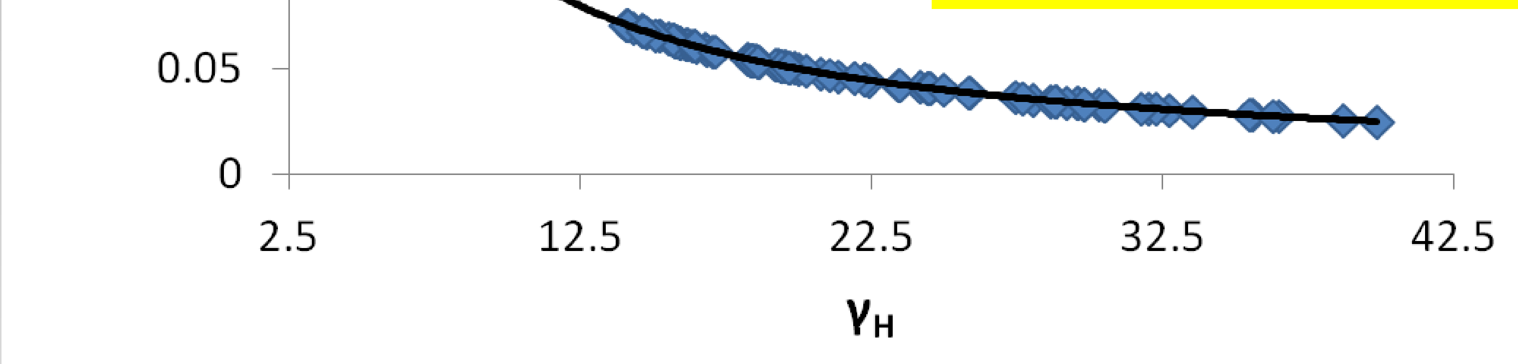


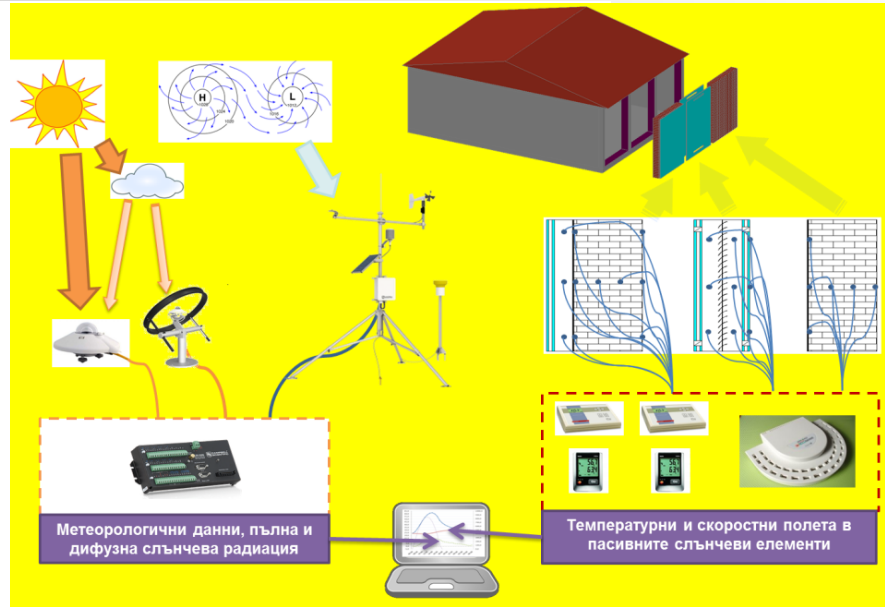




Parametric analysis of the heat utilization factor

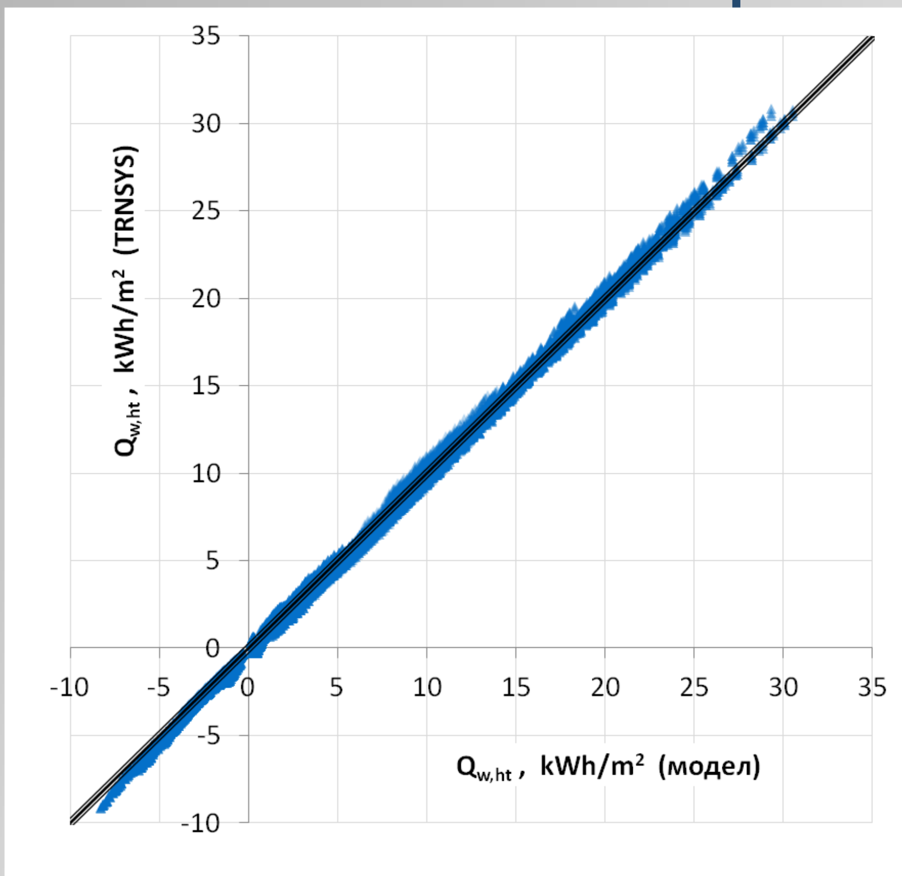
$$Q_{H,nd} = Q_{H,ht} - \eta_{H,gn} Q_{H,gn}$$

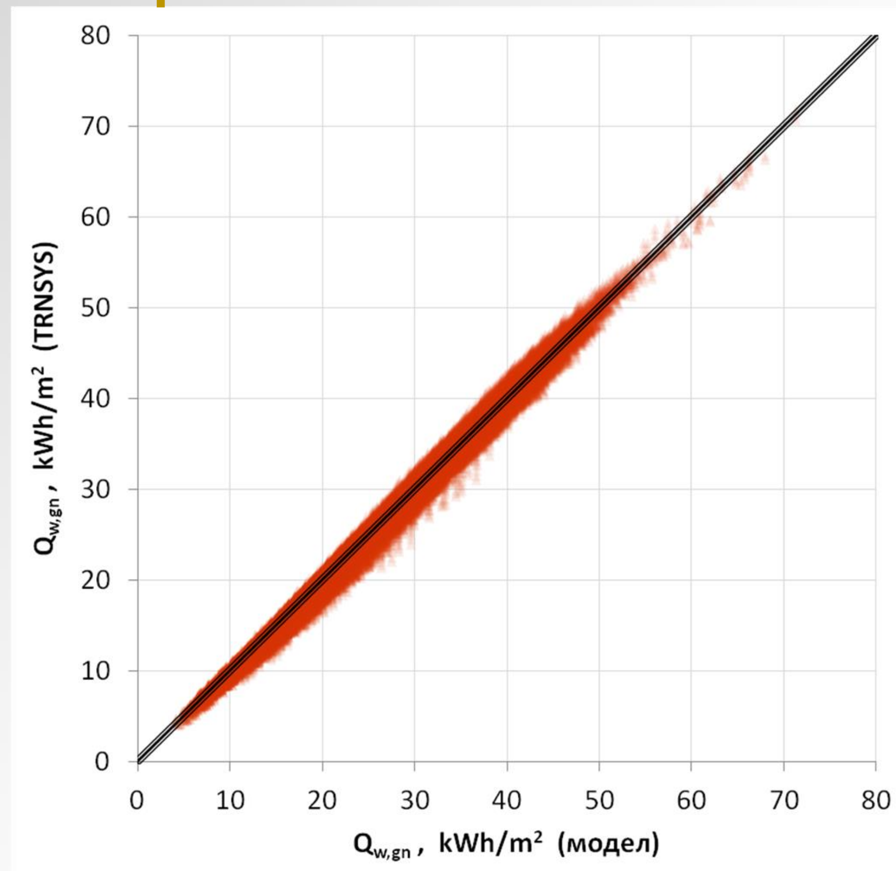




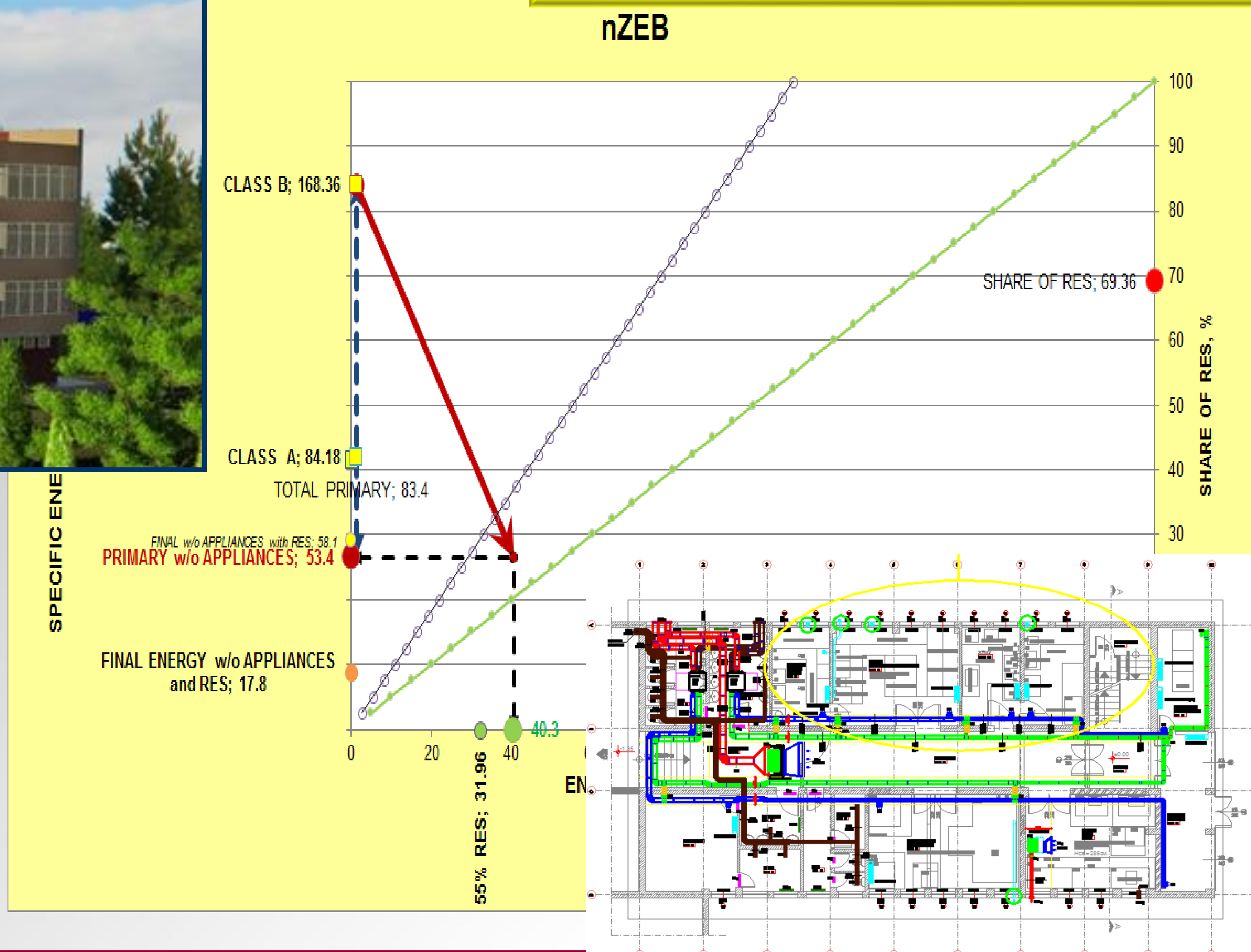
TECHNICAL UNIVERSITY - SOFIA

$$Q_{H,nd} = Q_{H,ht} - \eta_{H,gn} Q_{H,gn}$$



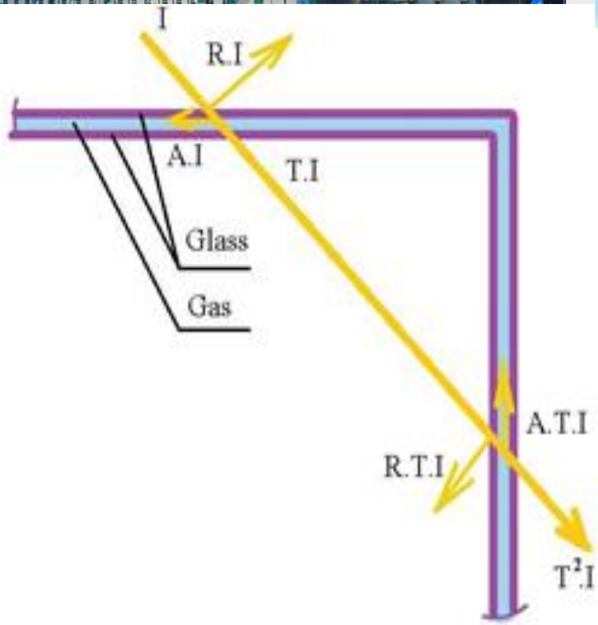


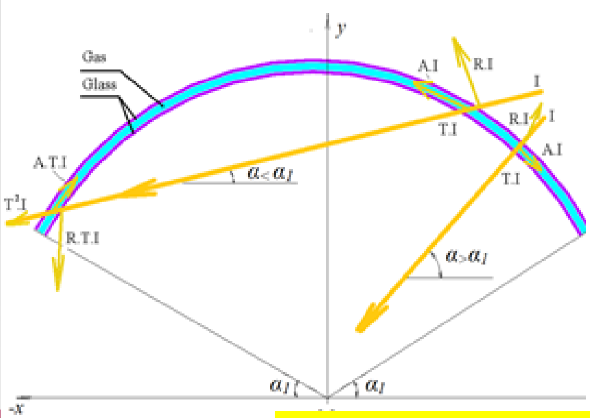
THE FIRST nZEB – the Technical university Research Centre, established under a project financed by the NRF



DFNI E 02/17" Parametric analysis for evaluation of the efficiency of transparent structures in systems for utilization of solar energy - with partners: ***the University of Chemical Industry and Metallurgy - Sofia, the Technical University of Sofia and the Technical University Angel Kanchev- Rousse***

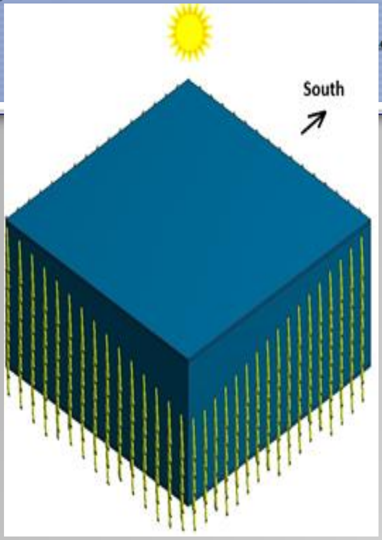
UCIM-Sofia:Complex heat exchange in large-scale transparent building fences



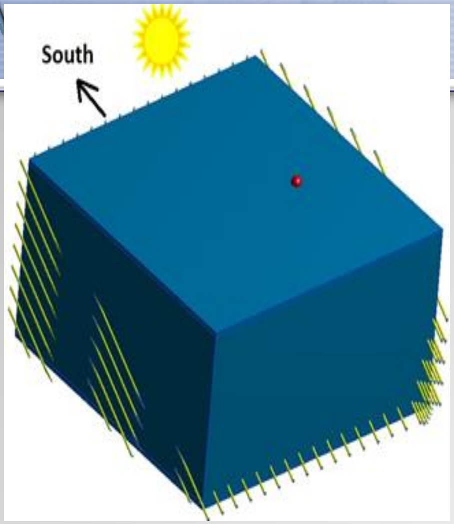


Indoor solar ray tracing

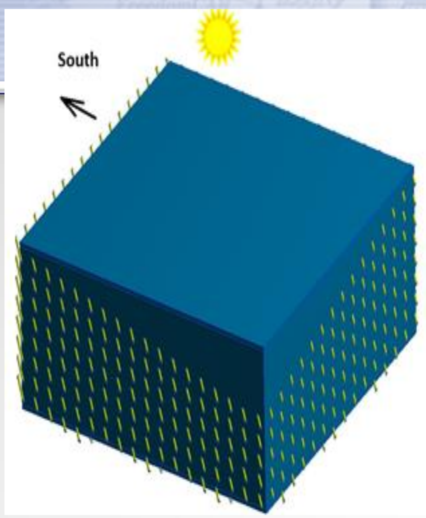
Sunlight on "transparent" flat walls



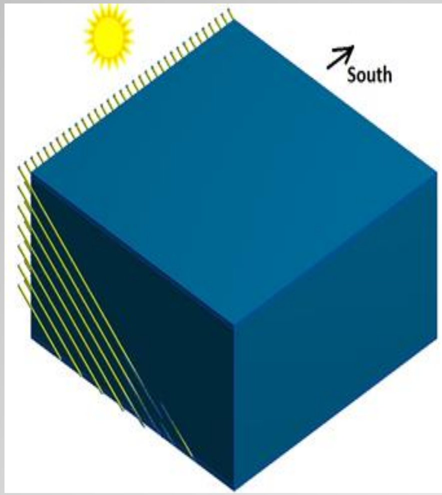
9.00h on December 15



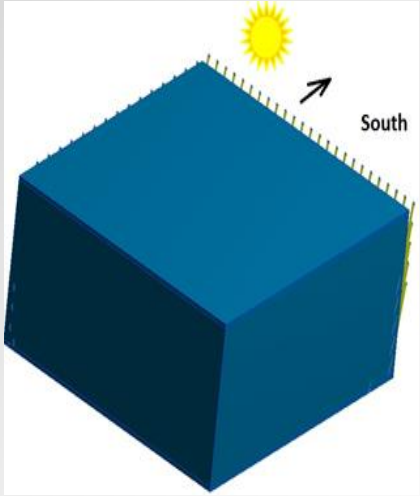
13.00h on December 15



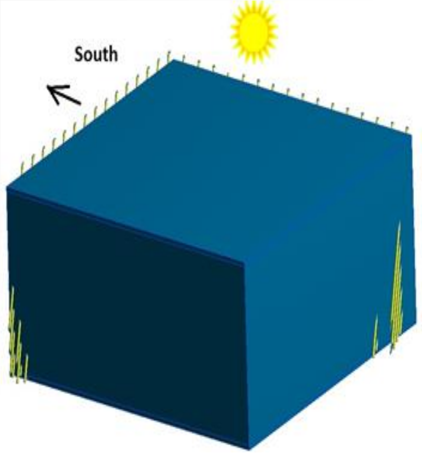
16.00h on December 15



9.00h on July 15

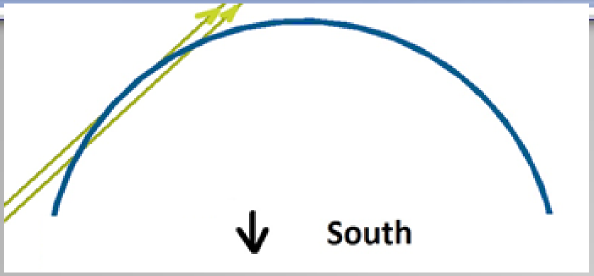


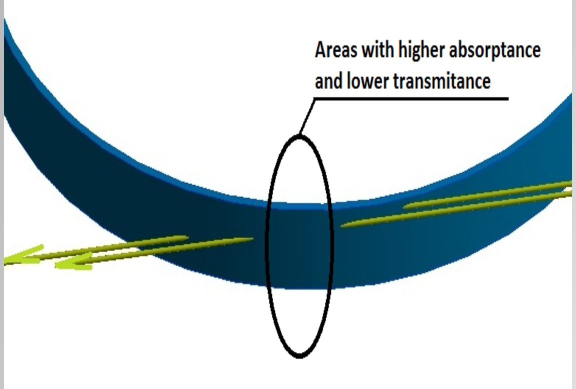
13.00h on July 15

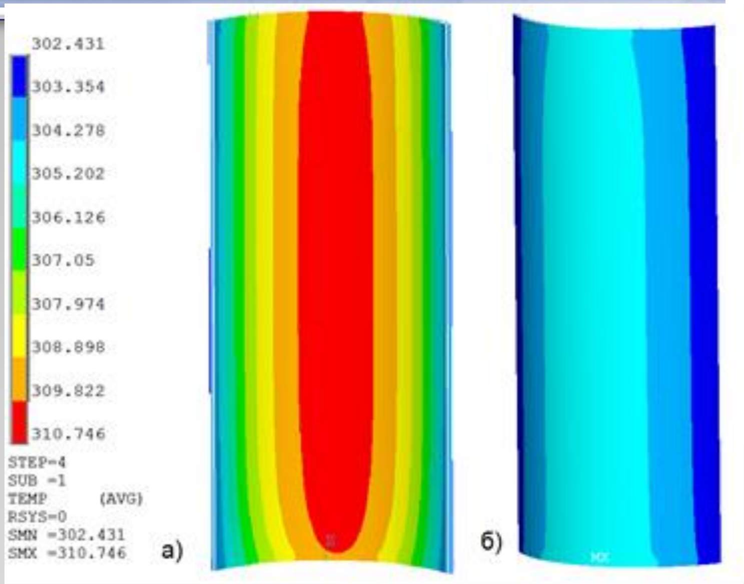


16.00h on July 15

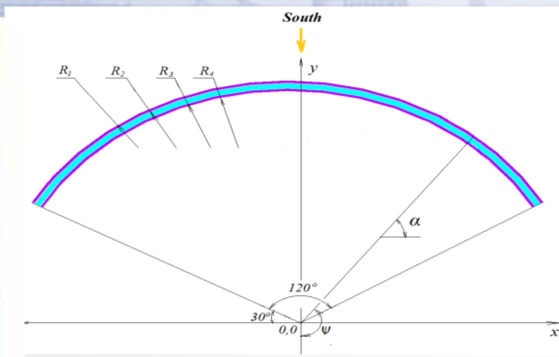
Sunlight on curved transparent walls

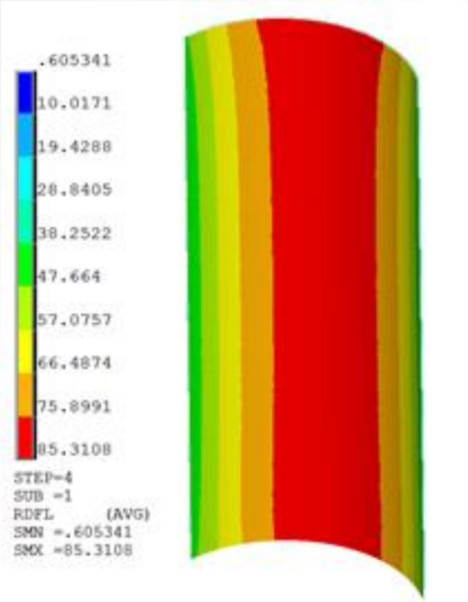






Temperature field in a double semi-cylindrical glass package
a) ext. surface
b) int. surface





Density of the radiation flux emitted from the inner surface

Heat load on curved surfaces:

- **unequal heat flux density;**
- **uneven passage, absorption and reflection ability;**
- **uneven temperature field and temp. gradients.**

Effects of sunlight on transparent enclosures with non-zero angular radiation coefficients

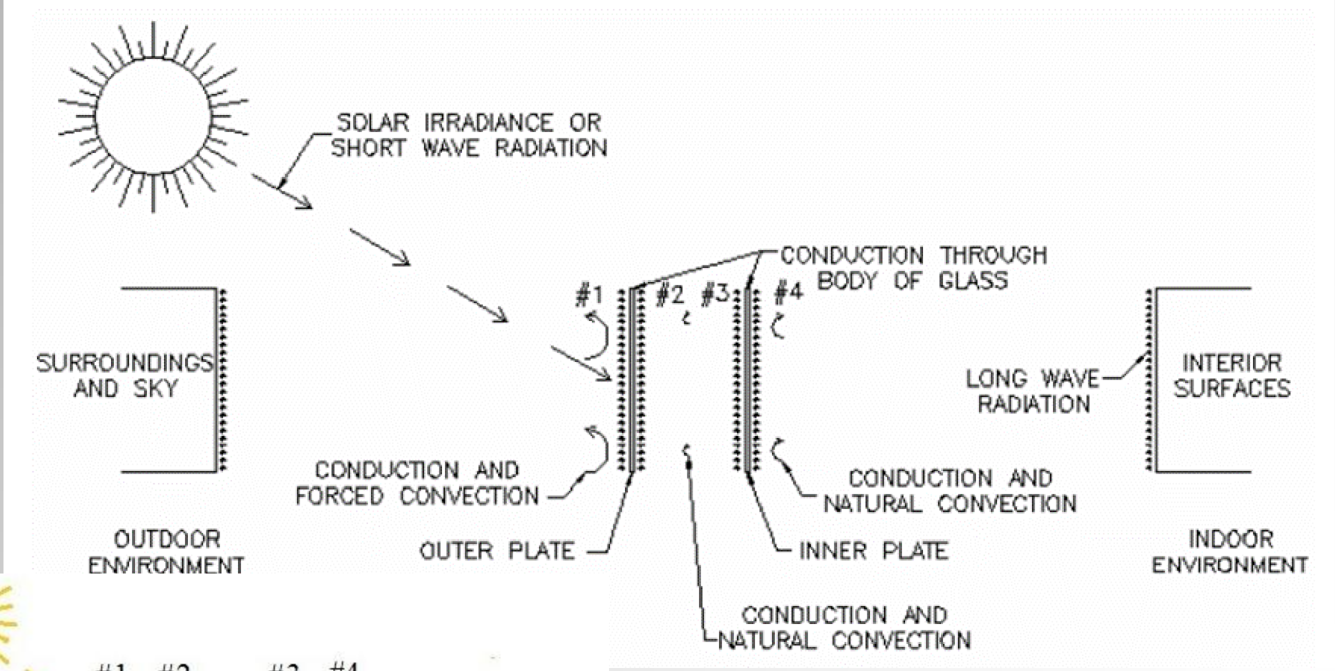
- **Inaccuracy in the assessment of solar gains in buildings**
- **Radiation asymmetry and greenhouse effect in the premises**

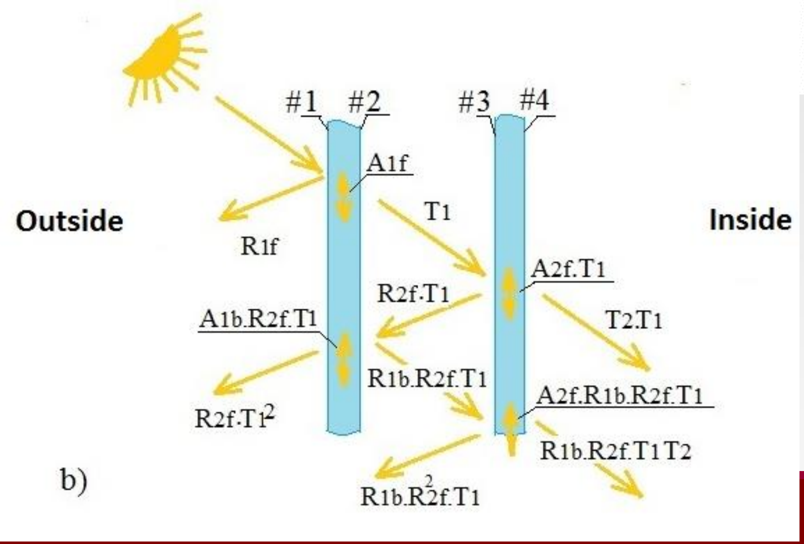
The upper limit for the permissible temperature difference between the temperatures of the inner surfaces of the walls and the remaining internal surfaces is 23 K. The solar energy absorbed by the glasses leads to an increase in their temperature: in the presence of sunshine, the internal glass temperatures are higher than those of the massive walls. This effect is more pronounced in coated glasses as their absorption capacity is higher than the absorption capacity of uncoated glass.

- **Additional thermal loads of building glass elements**

UCIM-Sofia:Influence of non-steady state heat transfer on the heat load of glass panes

Heat-exchange and heat load in double glazing in the presence of sunshine





Processes causing mechanical stresses and deformations of the elements in glass panes:

- **Temperature extensions;**
- **Internal loads**

Objective: to create an algorithm for predicting thermo-mechanical behavior and the possibility of fatigue of transparent elements of glass-packets in the seasonal variation of climatic conditions and solar radiation.

Modeling of conjugated heat exchange through glazing units

Practice shows that non-stationary temperature fields in transparent facade elements with practical accuracy can be considered as a sequence of stationary ones, resulting from boundary conditions reflecting current weather conditions.

System of equations based on differential method.

Fluid environment (pressurized gas space of glass):

- continuity equation;
- motion equations;
- energy equation;
- model of turbulence;
- models of dynamic and thermal boundary layer.

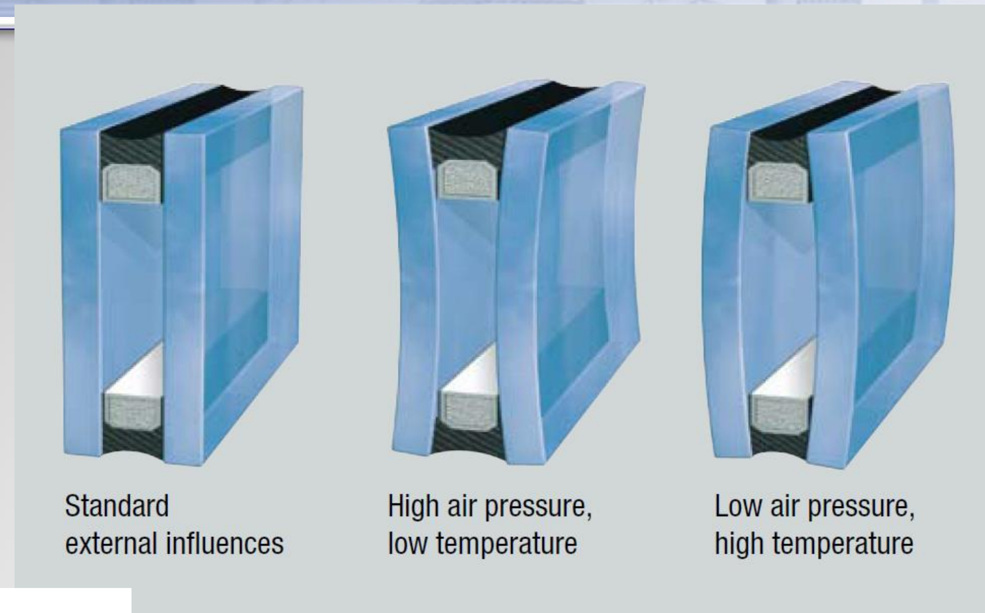
Non-fluid medium (glass sheets, spacer, gaskets):

- Energy equation for rigid fixed environment (Fourier-Kirchhoff).

The surfaces limiting the pressurized gas space form a closed system. Modern computational simulation environments offer possibilities for calculating angular coefficients and heat exchange by emitting between the "mutually visible" surfaces of the finite elements / volumes in closed and open systems [Radiosity solver method].

- **As a result of the numerical studies of the heat exchange in the glass panes, information on the variation of the internal load due to the change in the temperature of the pressurized gas was obtained within the individual days and months. It has been found to change several times a day and, in the absence of additional components, will cause deformation of windows in opposite directions during the winter and summer months.**
- **The resulting numerical values of the overpressure and the under pressure in the sealed gas space allow for prediction of the total internal load in the surveyed structure in terms of the possible variation of the meteorological pressure and of the altitudes at the places of production and installation of the glass pane. This information makes it possible to investigate the cyclic mechanical deformations, stresses, and the fatigue potential of building glass elements.**

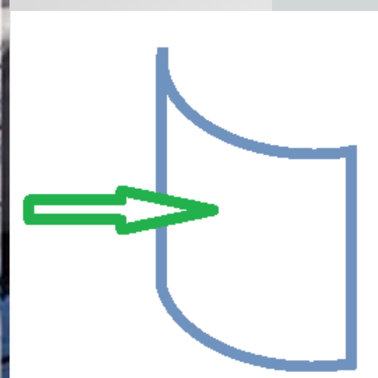
Thermo mechanical processes in flat and curvilinear glass

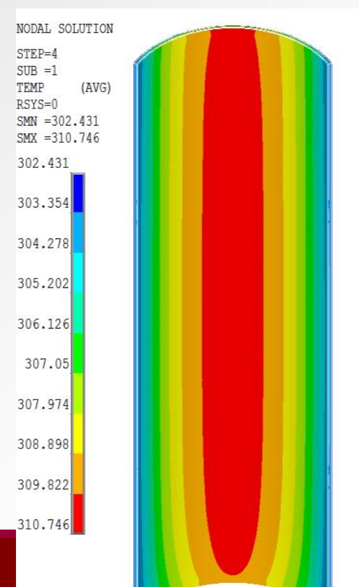


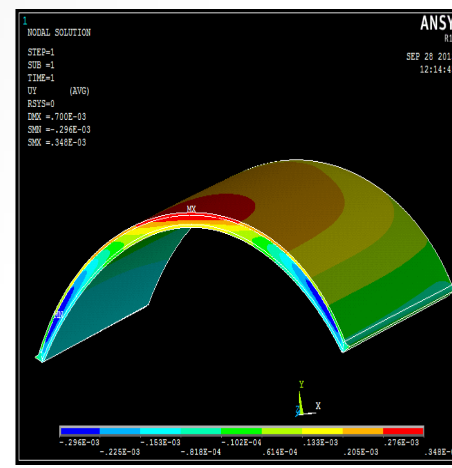
Internal loads on glass panes

$\Delta p_{is} = C_1 . \Delta T - \Delta p_{met} + C_2 . \Delta H$

$C_1 = 0{,}34$ kPa/K; $C_2 = 0{,}012$ kPa/m

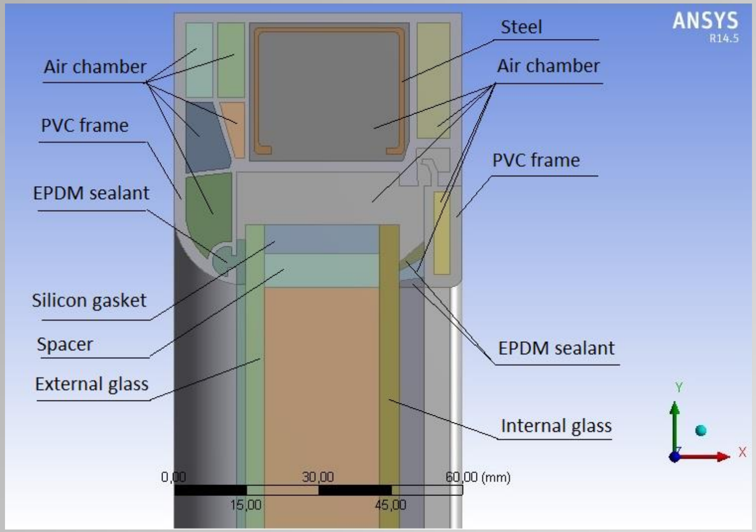


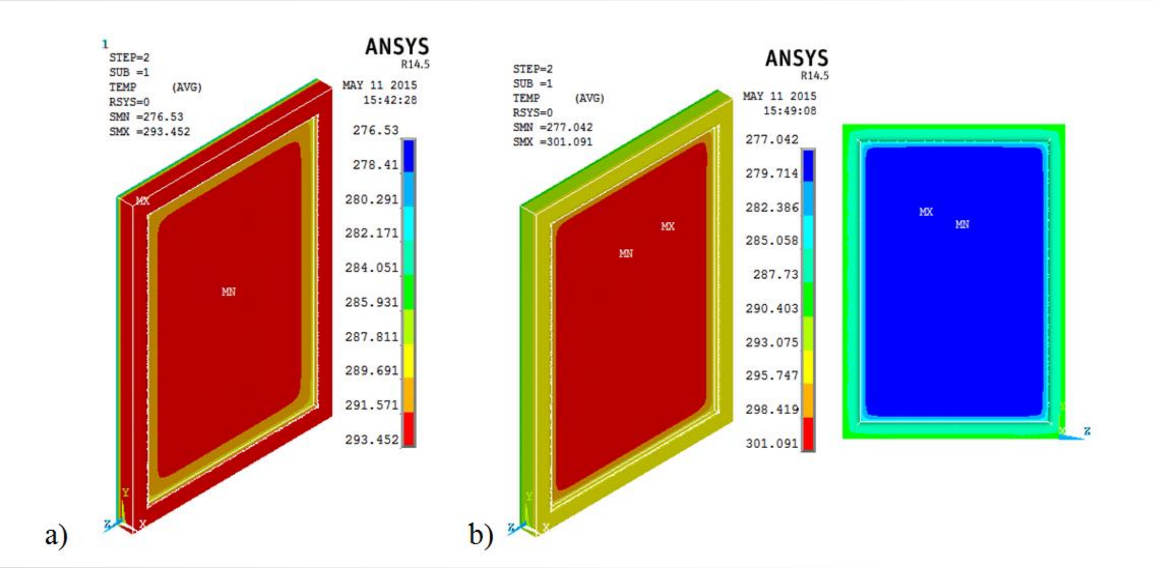




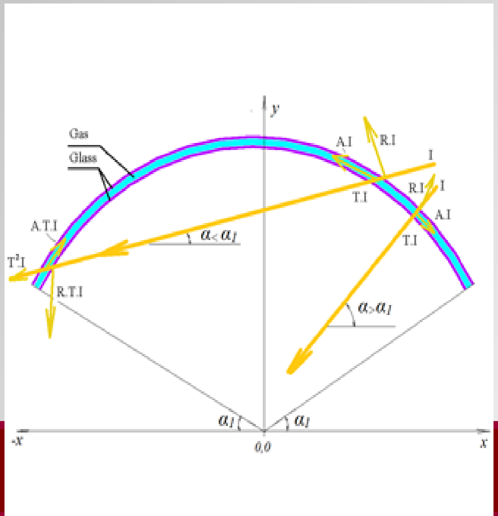
Деформации

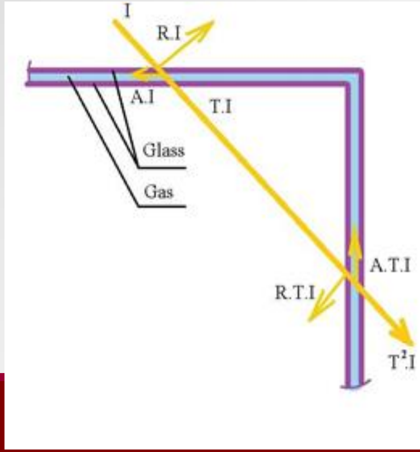
Numerical studies of heat exchange in window systems





Temperature fields under standard test conditions to determine U, W/(m²K)





Indoor solar ray tracing

Subject of research: transparent structures in passive systems: direct passive systems, Trombe's wall

Parametric analysis to evaluate the effectiveness of transparent structures

Parameters

- Energy characteristics that affect solar energy recovery
- Reliability
- Embodied energy
- "Energy Payback Time"
- Technical life

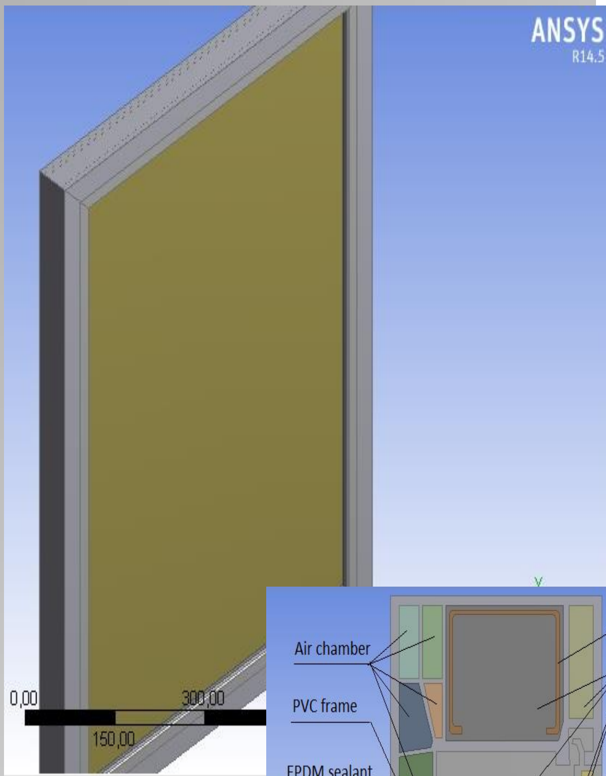
Analysis of energy performance deviations of transparent structures under operating conditions as determined by standardized methods

Algorithm for assessing the impact of transparent structure parameters on their reliability and lifecycle

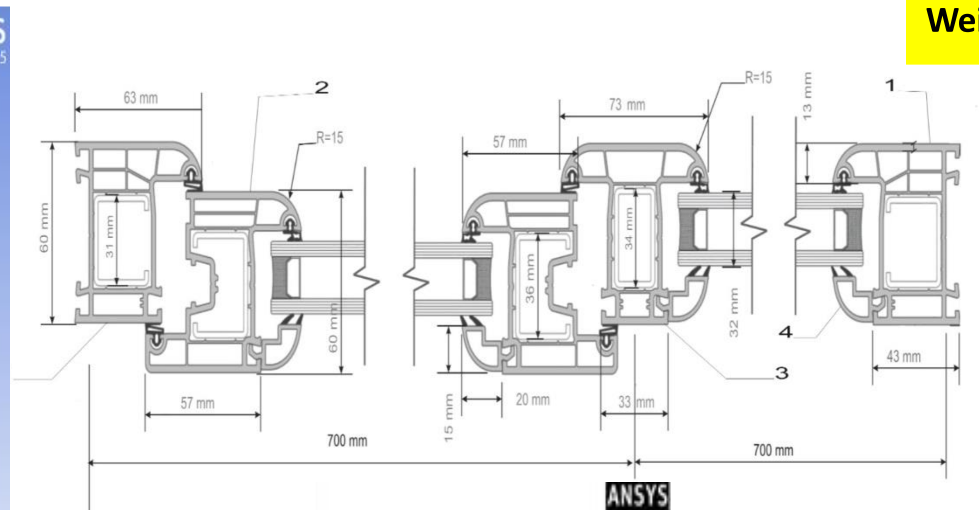
Concept of the use of research results in the methodologies for research and evaluation of the energy efficiency of passive solar systems

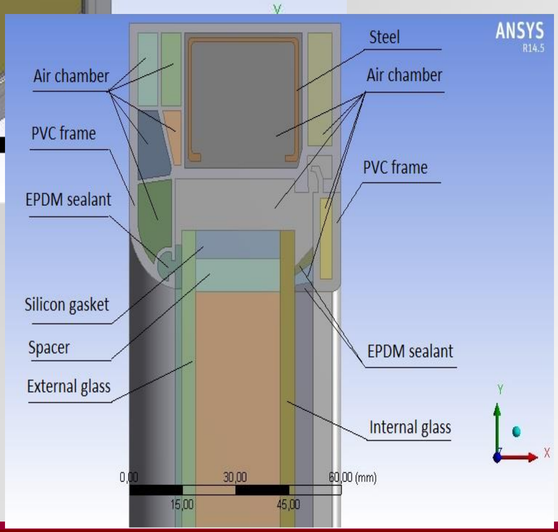
Algorithm for parameterized model studies of transparent structures aimed at increasing the positive effect of their life cycle and the energy efficiency of passive systems

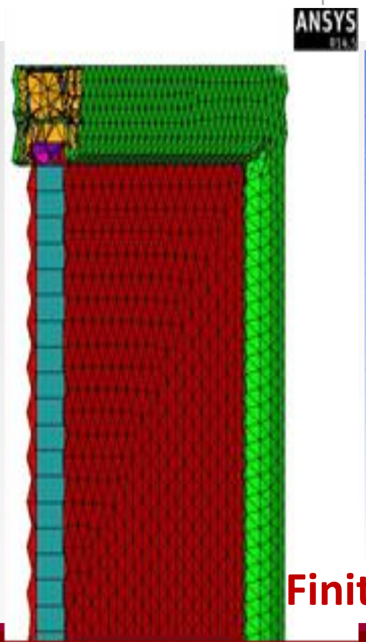
THERMAL LOAD ANALYSIS OF INSULATING WINDOW SYSTEMS

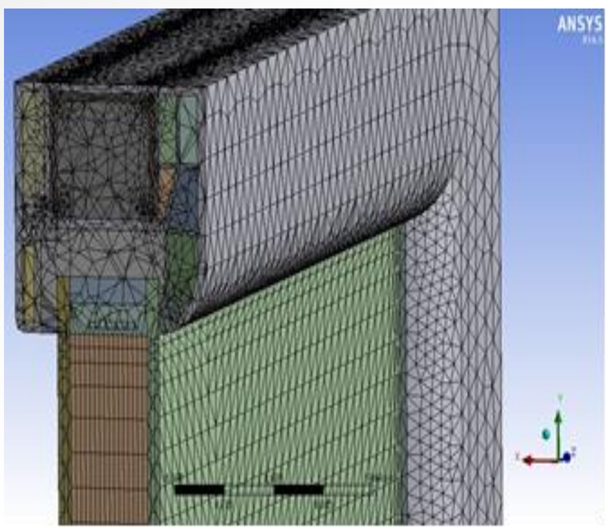


Weiss Profile LTD







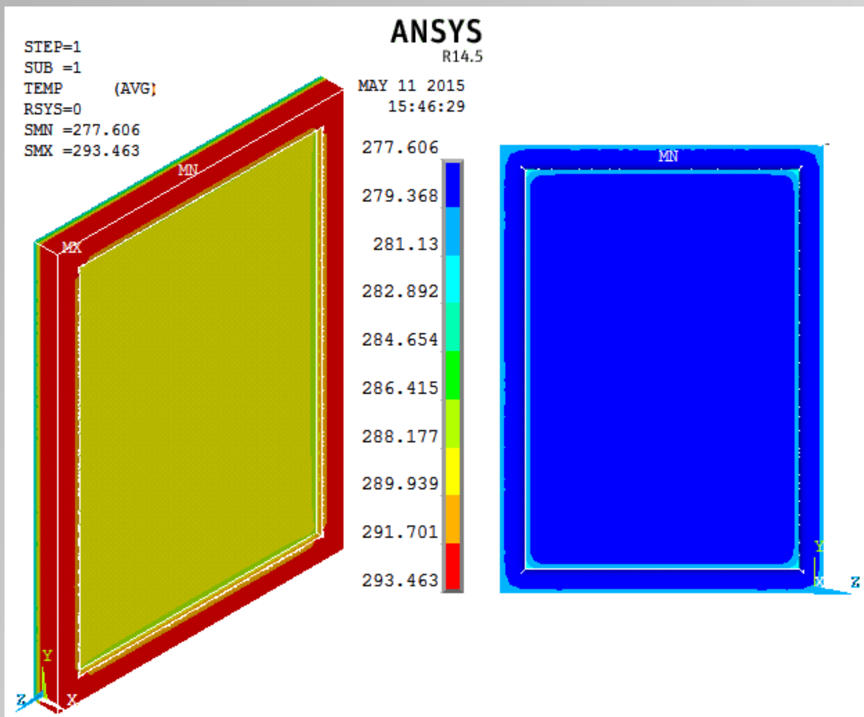


Finite volumes (Ansys Workbench)

Finite elements (Ansys APDL)

THERMAL LOAD ANALYSIS OF INSULATING WINDOW SYSTEMS

a)



b)

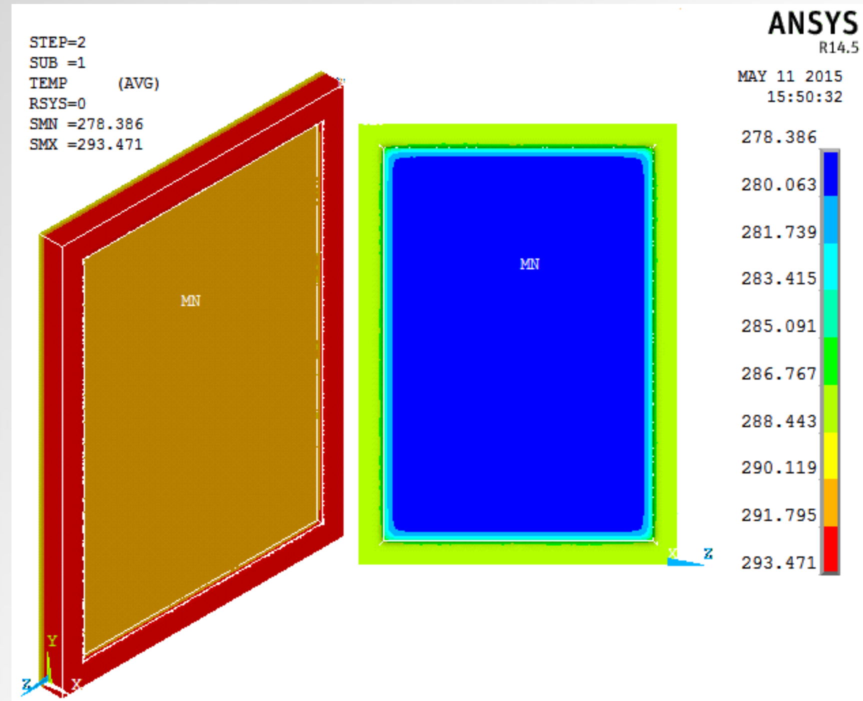


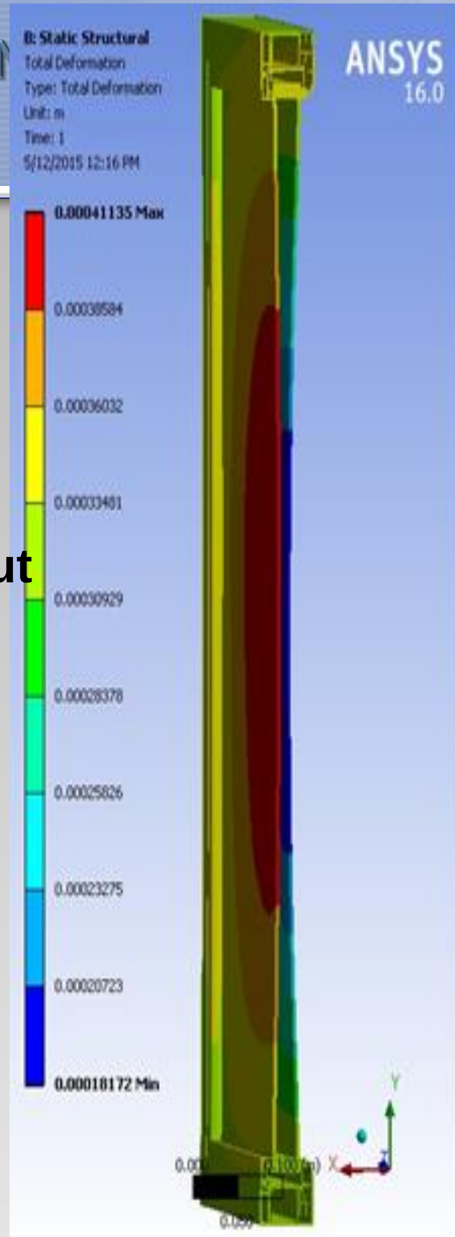
Figure 4. Temperature fields at window without coatings

a) Hot box conditions; b) Winter conditions in presence of solar irradiation

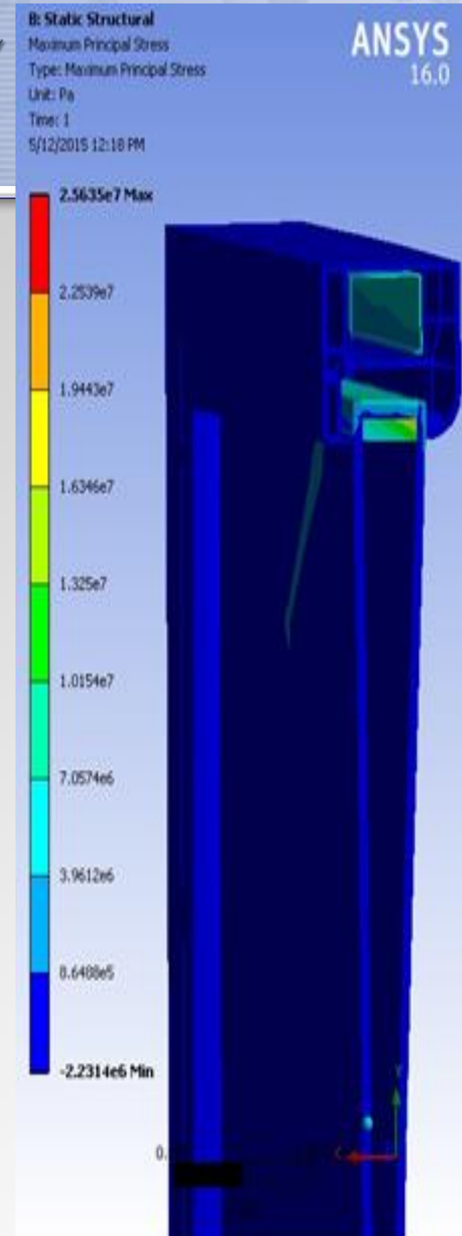
Average temperature and isochoric pressure of the hermetically sealed gas (argon)

Numerical experiments	Test conditions at Hotbox chamber t_{in}=21°C, t_{out}=3°C h_{si}=3,6 W/m^{2}K^{-1} h_{se}=23 W/m^{2}K^{-1} (Analysis by ANSYS APDL/Flotran)	Daily winter conditions with solar irradiation t_{in}=21°C, t_{out}=3°C, t_{sky}= -10 °C, F_1=0.5; I_s=350 W/m^2 h_{si}=3,6 W/m^{2}K^{-1} h_{se}=23 W/m^{2}K^{-1} (Analysis by ANSYS APDL/Flotran)	Night winter conditions t_{in}=21°C, t_{out}=3°C t_{sky}= -10 °C; F_1=0 h_{si}=3,6 W/m^{2}K^{-1} h_{se}=23 W/m^{2}K^{-1} (Analysis by ANSYS/Fluent)
Window system with low-e coating on surface 3	t_{gas}=11°C ΔT=-9 K Δp_{is}=-3060 Pa	t_{gas}=16°C ΔT=-4 K Δp_{is}=-1360 Pa	t_{gas}=11°C ΔT= -9.2 K Δp_{is}=3106 Pa
Window system without coatings on the glass surfaces	t_{gas}=10°C ΔT=-10 K Δp_{is}=3400 Pa	t_{gas}=12°C ΔT=-8 K Δp_{is}=-2720 Pa	-
UGU with low-e coating on surface 3	t_{gas}=11°C ΔT=-9 K Δp_{is}=3060 Pa	-	-

Night winter conditions without solar radiation



Total displacements



Maximum principal stress

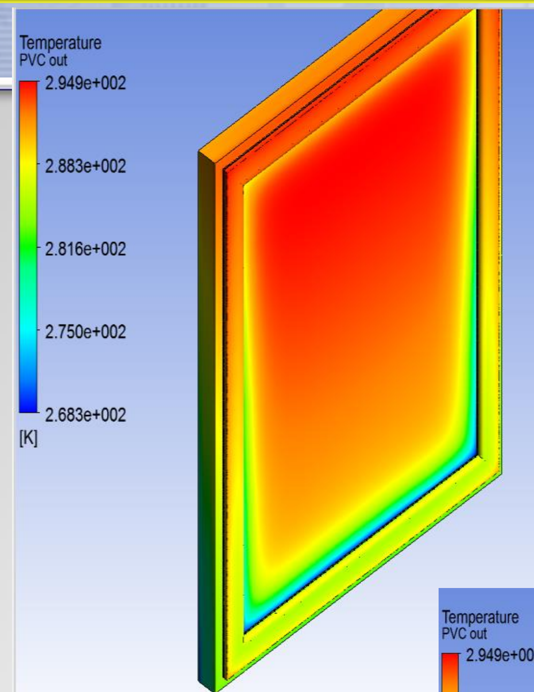
The inner load produces tension on the inner surface of the glass panes and compression on the outer. It is expected that the situation will be changed with the climate conditions: the inner surface will be compressed in the hot seasons (summer).

Thermal analysis at hot box conditions

Measurements of the temperatures and glass deflection in a hot box chamber

Tout[K]= 267[K]+16.21[K/m]*y

hse=25 $Wm^{-2}K^{-1}$ and : hsi=3.6 $Wm^{-2}K^{-1}$



Temperature fields at inner window surface

Temperature fields at outer window surface

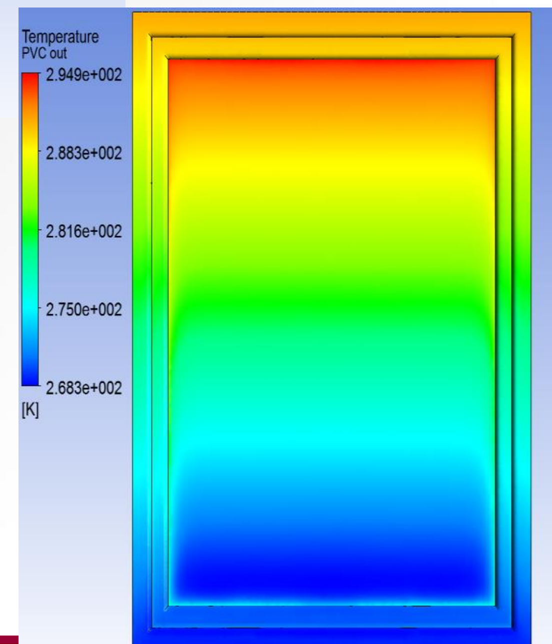
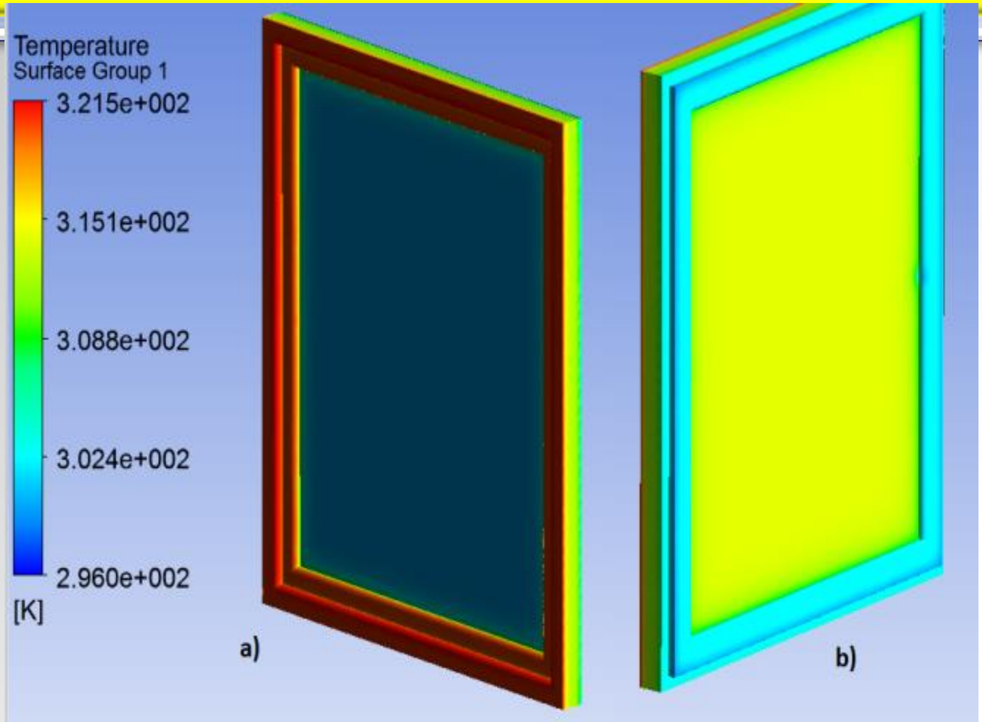


Table1: Conditions for numerical simulations

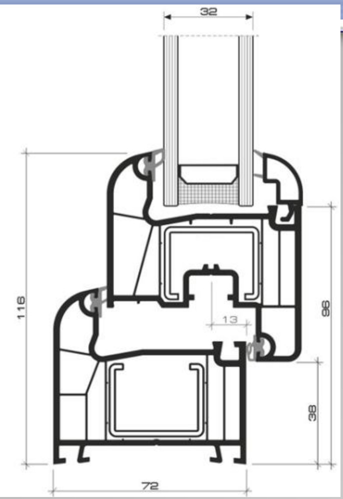
Numerical experiments	Boundary conditions (numerical expressions)
Sumer conditions [12] July, daily–time: 9 a.m. T_{in}=297 K (24°C) T_{out}=297 K (24°C) T_{sky}=283 K (10°C) $T_{r.m}$=290 K F_1= F_2=0.5 I_s=740 Wm^{-2} h_{si}=7.7 $Wm^{-2}K^{-1}$ h_{se}=20 $Wm^{-2}K^{-1}$	External frame surfaces $\dot{q}^{f}_{se} = 20*(297-T)+$ $+5.67*10^{-8}*0.95*(290^4-T^4)+0.95*740$ External glass surfaces $\dot{q}^{g}_{se} = 20*(297-T)+$ $+5.67*10^{-8}*0.84*(T^4_{r,m}-T^4)+0.12*740$ Internal surfaces $\dot{q}_{si} = 7.7(297-T)$ Surface 3 at IGU (coated glass surface): $\dot{q}_3 = 0.22*740$
Winter conditions January, night- time T_{in}=293 K (20°C) T_{out}=257 K (-16°C) T_{sky}=227 K(-46 °C) F_1= F_2=0.5 I_s=0 Wm^{-2} h_{si}=7.7 $Wm^{-2}K^{-1}$ h_{se}=20 $Wm^{-2}K^{-1}$	External frame surfaces $\dot{q}^{f}_{se} = 20*(257-T)+$ $+5.67*10^{-8}*0.95*(244^4-T^4)$ External glass surfaces $\dot{q}^{g}_{se} = 20*(257-T)+$ $+5.67*10^{-8}*0.84*(244^4-T^4)$ Internal surfaces $\dot{q}_{si} = 7.7(293-T)$ Surface 3 at IGU (coated glass surface): $\dot{q}_3 = 0$

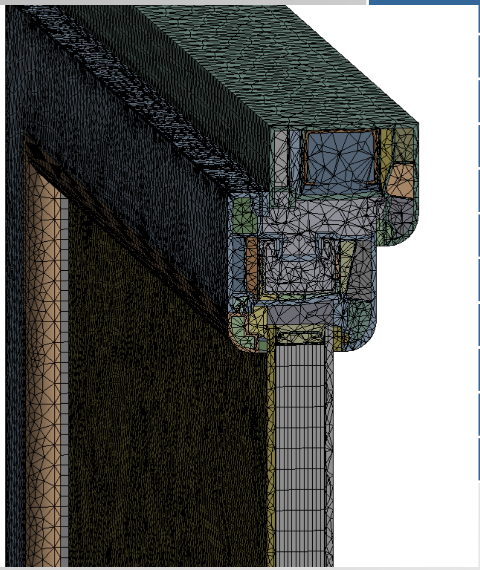
Thermal analysis at winter and summer conditions



Summer conditions. Temperature fields at inner (a) and outer (b) window surfaces

Influence of Coatings on the Thermal and Mechanical Processes in Insulating Glass Units



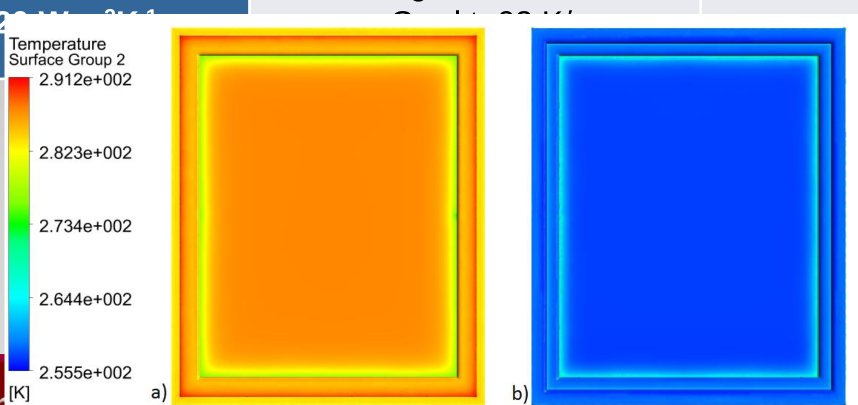


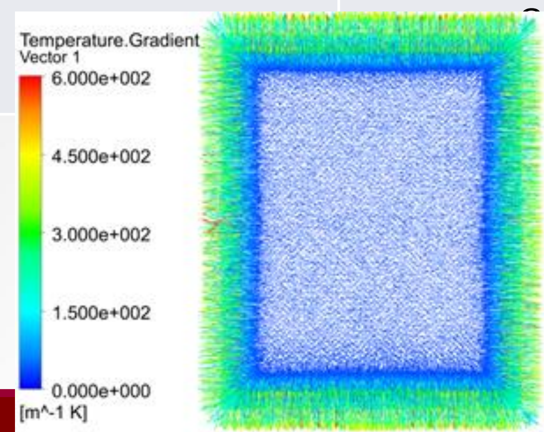
Thermal and solar characteristics	Variant 1. Panes 1 and 2 – uncoated *	Variant 2. Pane 1 - low emissivity coating on surface 2**; pane 2 – uncoated*	Variant 3 Pane 1 - solar control coating on surface 2***; pane 2 – uncoated*
ε_1^f	0.84	0,84	0.84
ε_1^b	0.84	0.16	0.17
A_1^f	0,12	0,22	0,47
A_1^b	0.12	0.22	0.45
R_1^f	0,07	0,11	0,08
R_1^b	0.07	011	0.12
T_1	0,81	0,67	0,45
ε_2^f	0.84	0.84	0.84
ε_2^b	0.84	0.82	0.84
A_2^f	0,12	0,12	0,12
A_2^b	0.12	0.12	0.12
R_2^f	0,07	0,07	0,07
R_2^b	0.07	0.07	0.07
T_2	0,81	0,81	0,81
$\hat{A}_1$	0.13	0.23	0,48
$\hat{A}_2$	0.08	0.08	0,05

*Pilkington Optifloat clear glass; ** Pilkington Energy Advantage™; *** Pilkington Solae-E™

Influence of Coatings on the Thermal and Mechanical Processes in Insulating Glass Units

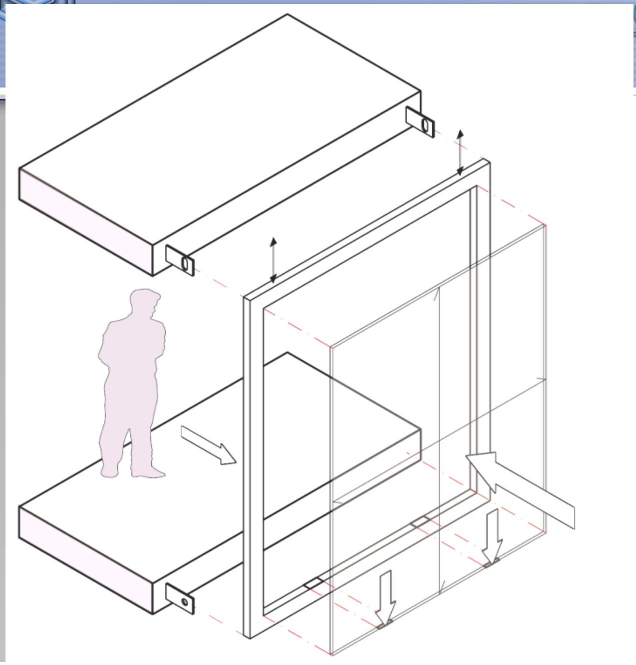
Conditions	Variant 1 Panes 1 and 2 –uncoated	Pane 1 - low emissivity coating on surface 2; pane 2 – uncoated	Pane 1 - solar control coating on surface 2; pane 2 –uncoated
Sumer conditions [13] **July, daily–time: 9a.m.** **T_{in}=297 K (24°C)** **T_{out}=297 K (24°C)** **T_{sky}=283 K (°C)** **$T_{r,m}$=290 K** **F_1= F_2=0.5** **I_s=740 Wm^{-2}** **h_{si}=7.7 $Wm^{-2}K^{-1}$** **h_{se}=20 $Wm^{-2}K^{-1}$**	T_{gas}=303 K (30°C) ΔT= 10 K; Δp_{is}= 3.4 kPa <u>External glass pane</u> Average temperature T_{av} =301 K Average temperature gradients Grad t=38 K/m	Tgas=302 K (29°C) ΔT= 9 K; Δp_{is}= 3.06 kPa <u>External (coated) glass pane</u> Average temperature T_{av} =303 K Average temperature gradients Grad t=21 K/m	T_{gas}=305 K (32°C) ΔT=12 K; Δp_{is}= 4.08 kPa <u>External (coated) glass pane</u> Average temperature T_{av} =310 K Average temperature gradients Grad t=12 K/m
Winter conditions **January, night- time** **T_{in}=293 K (20°C)** **T_{out}=257 K (-16°C)** **T_{sky}=227 K(-46 °C)** **$T_{r,m}$=244 K** **F_1= F_2=0.5 ; I_s=0** **h_{si}=7.7 $Wm^{-2}K^{-1}$** **h_{se}=2**	Tgas=271 K (-2°C) ΔT=-22 K; Δp_{is}= -7.48 kPa <u>External glass pane</u> Average temperature T_{av}=260 K Average temperature gradients		T_{gas}=272 K (-1°C) ΔT=-21 K; Δp_{is}= -7.14 kPa <u>External (coated) glass pane</u> Average temperature T_{av} =258 K Average temperature gradients ad t=74 K/m

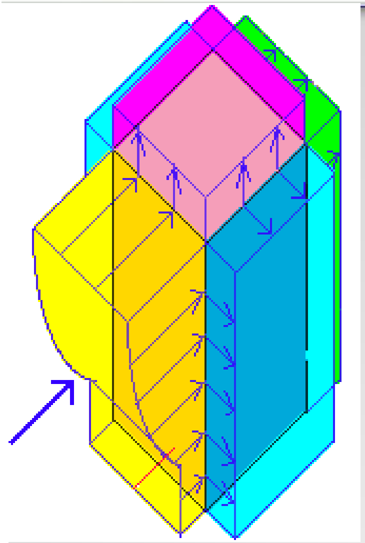




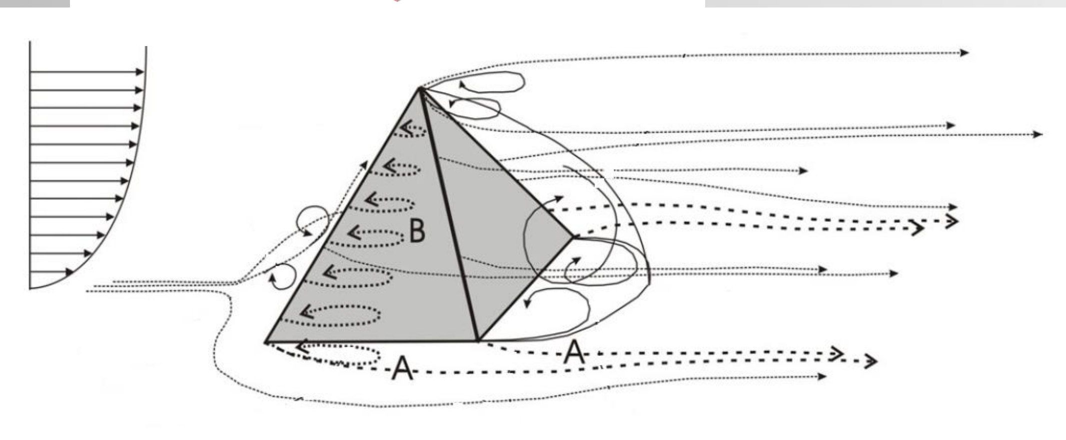
The TU-Rousse: Strength and deformation analysis of glass structures

Loads and impacts

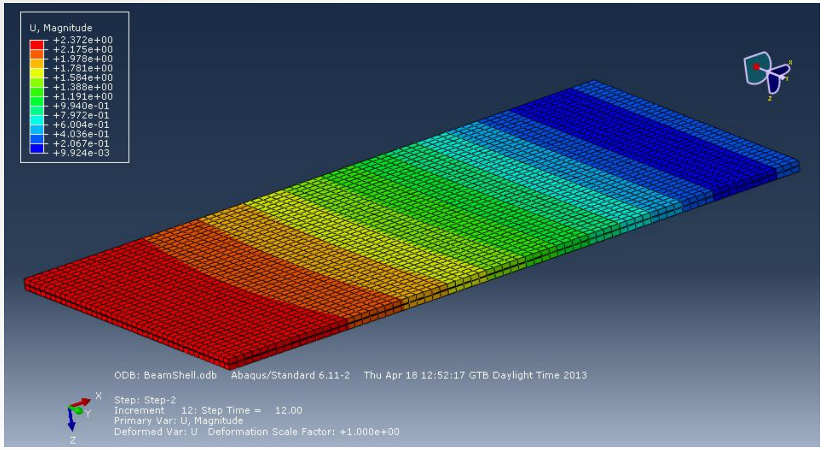




- Own weight
- Wind (in both directions)
- Snow
- Loading from people
- Climate loads - change of temperature and humidity
- Seismic

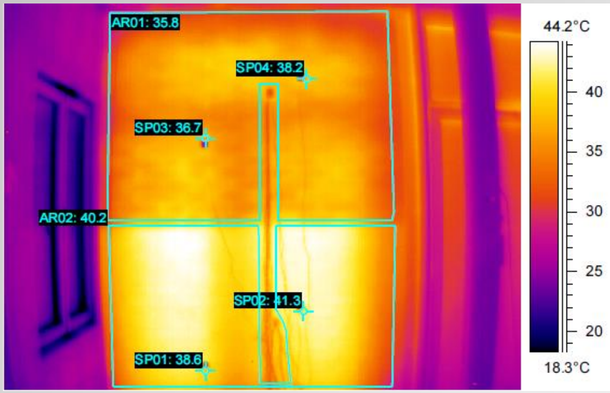


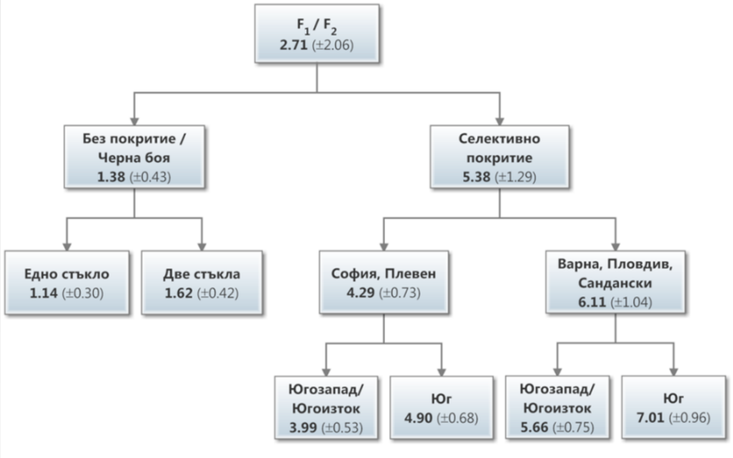
Loads with complex distributions!

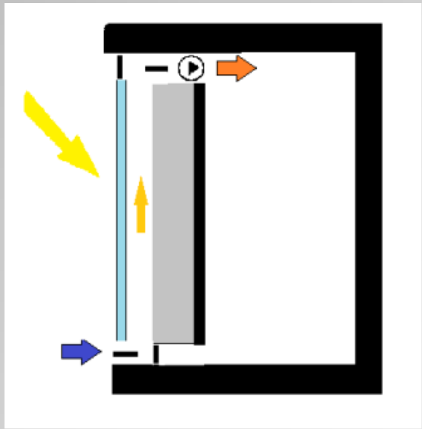


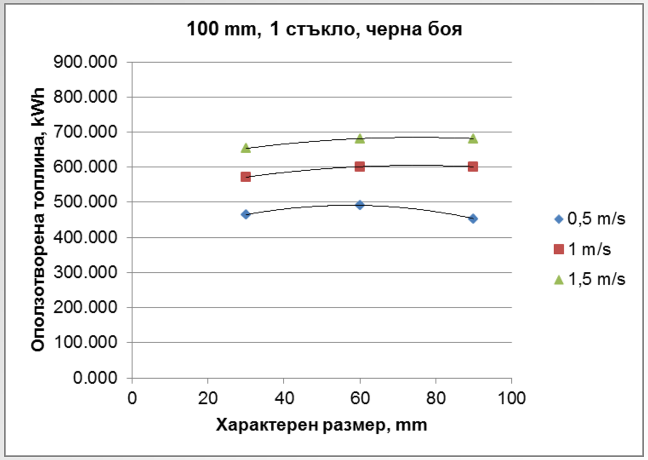
Finite element method analysis

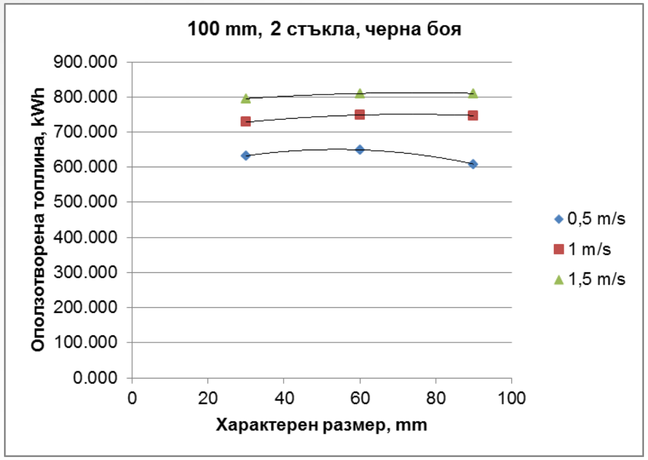
The TU-Sofia: Experimental study of passive glassed structures











EXPECTED RESULTS

The expected results of integrating the knowledge, experience and resources can be summarized as follows:

- A new high-tech material base has been created;
- The competence of the research teams is enhanced and synergies are observed;
- Enhanced capabilities of small and medium-sized enterprises (SMEs) for access to high technology in engineering, as well as a more active exchange of knowledge and experience between SMEs and research teams;
- Transfer of knowledge to the industrial enterprises and opportunities for realization of the strategy for reverse transfer of resources to the research laboratories of the universities-partners;
- Enhanced competence of students and PhD students involved in project's activities with a long-term effect on the industry, where they will realize their knowledge and skills.

THANK YOU!