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OFFICE BUILDING WITH ENVIRONMENTALLY ADAPTABLE ENVELOPE
CASE STUDY

BY

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Abstract. The paper compares the energy performance of an existing office building - the ”Centris” Center in the city of Iasi – considering several solutions for the building envelope. The existing static envelope is successively modified by installing sets of dynamic solutions as follows: 1) mobile shading system with adjustable wooden blades, with and without insulation (aerogel), meeting the shading requirement, 2) 4-chamber ETFE air-cushions, replacing the existing glazing, that can inflate or deflate according to specific calculated periods, 3) integration of PV panels into the mobile shading system and PV cells into the ETFE air cushions. The results show that the optimal solution is to use ETFE air-cushions with PV cells for the transparent envelope surfaces, diminishing the heating and cooling energy demand by 85.22%, compared to the existing building. Also, by integrating a mobile shading system with PV panels, the energy demand is reduced by 66.48%.

Keywords: energy efficiency; mobile shading; ETFE air cushions; PV cells; renewable energy.

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1. Introduction

The case study presented in the paper is analyzing the opportunities offered by the adaptable envelopes to environmental factors in order to reduce the building energy demand. The traditional static façade is designed to best respond to all the environmental conditions the building will experience over a year, while an adaptable façade has the ability to respond to changing indoor or outdoor climate conditions, influencing the indoor space comfort, with positive effects on the building energy efficiency.

Fig. 1 – Bird-eye perspective –”Centris” office building.

The subject of the study is an office building located in the city of Iasi (Center for Business Support for SMEs, ”Centris”) (Fig. 1), modelled with the Archicad programme, analysed with PHPP (Passive House Planning Package) and Design Builder simulation programmes, as well as with SolarPro - the solar panel performance assessment programme.

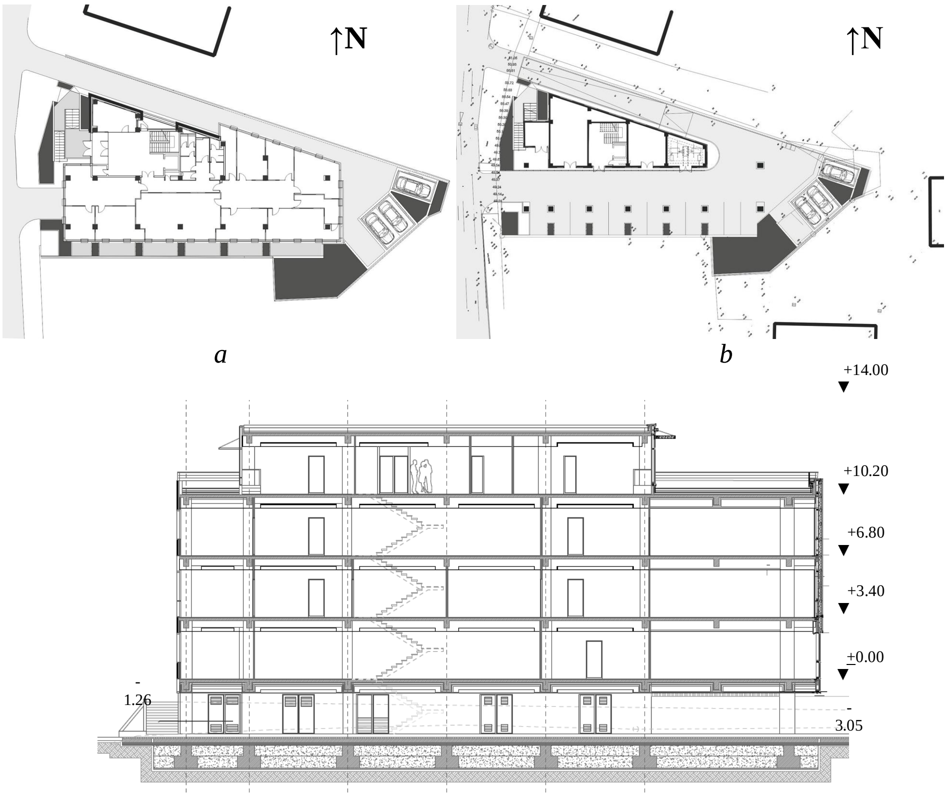
Built between 2013 and 2015, the office building has a height regime of semibasement + ground floor + 3 storeys and a developed area of 2,278.40 m^2, comprising individual and open space offices, meeting rooms and a conference room. The study uses as initial data the characteristics of the existing (static) envelope, which are then replaced, theoretically, by some solutions specific to adaptable envelope (mobile shading systems, ETFE (ethylene tetra-flour-ethylene) air cushions and integrated photovoltaic cells).

The study aims at:

a) demonstrating the advantages and disadvantages of static and dynamic envelopes that also integrate renewable energy sources;

b) formulating conclusions with practical applicability – supported by the theoretical results;

c) comparing the proposed solutions by considering the energy consumption from non-renewable/renewable sources.



a *b* *c*

Fig. 2 – Building architecture: *a* – ground floor, *b* – semi-basement, *c* – longitudinal section.

The building façades are realized with curtain walls, with the street side oriented towards the North-West (Fig. 2). The estimated number of users is 116, equivalent to a density of 0.068 pers./m^2.

The building envelope is composed by:

a) Vertical elements:

- glazing:

– three-leaf glass windows with outside opening in parallel plane, Schüco AWS 102, Ug = 1.3,...,2 W/m^{2}K;

– Schüco joinery FW 50 + SG.SI., Uf= 0.9,...,1.11 W/m^{2}K;

- opaque elements:

– Kingspan panels, 6 cm KS 1150TF/KS 1150TC, λ = 0.35 W/m^{2}K;

b) Horizontal elements:

- not trafficable terrace roof: 10 cm extruded polystyrene, reinforced concrete slab, concrete layer of variable height, diffusion-, decompression-, compensation layers, vapour barrier, 12 cm extruded polystyrene, protection screed, 2 layers of waterproofing membrane;
- trafficable roof terrace: 10 cm extruded polystyrene, reinforced concrete slab, concrete layer of variable height, diffusion-, decompression-, compensation layers, vapour barrier, 12 cm extruded polystyrene, protection screed, 2 layers of waterproofing membrane, protection screed, adhesive, fiberglass granite;
- floor over the parking area, facing the exterior (Fig. 2 *c*): bond plated ceiling, 20 cm extruded polystyrene, reinforced concrete slab, screed, parquet flooring.

The exterior walls of the last level, as well as some of the walls facing the South-West and South-East are protected by a shading system with fixed, light grey aluminium blades (Fig. 3 *a* and 3 *b*).

a *b*

Fig. 3 – *a* – fixed brise-soleil on the South-Eastern and South-Western façades; *b* – cantilever shading element at last level.

The results provided by the PHPP programme, after introducing the initial data, show the following values: 47 kWh/m^2 year for heating energy demand, 43 kWh/m^2year for cooling energy demand and 32% for overheating frequency.

2. Introducing a Mobile Shading System (1st Hypothesis)

Starting from the original building data and replacing the existing (fixed) shading system with a mobile one, with monthly adjustable blades installed on the South-Western and South-Eastern façades, the energy performance of the office building with this solution was calculated. Based on the graphical method, the blades inclination angle (Fig. 4) is determined so as to meet the shading requirement defined by the solar radiation utilization factor (Table 1).

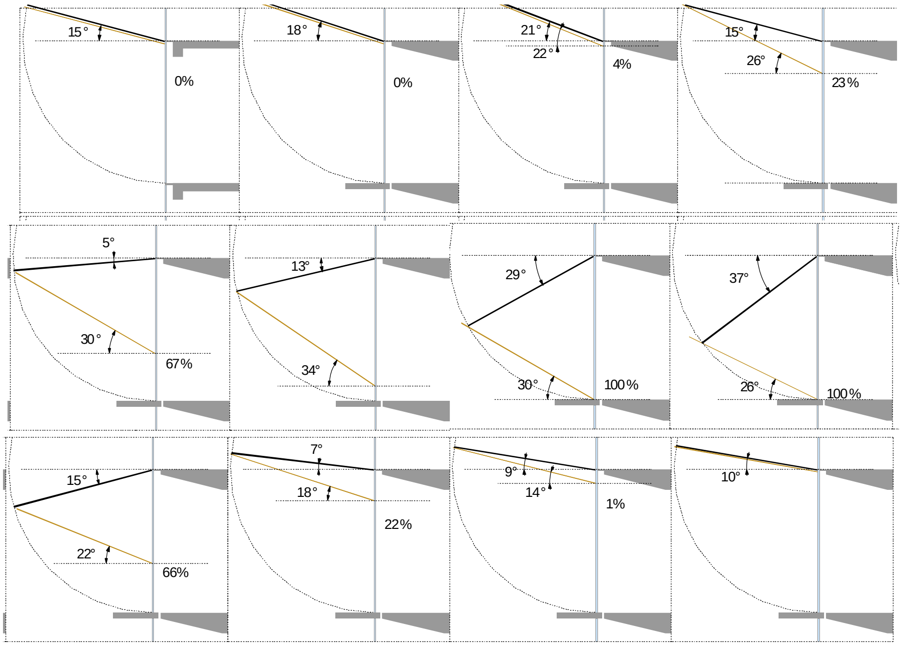
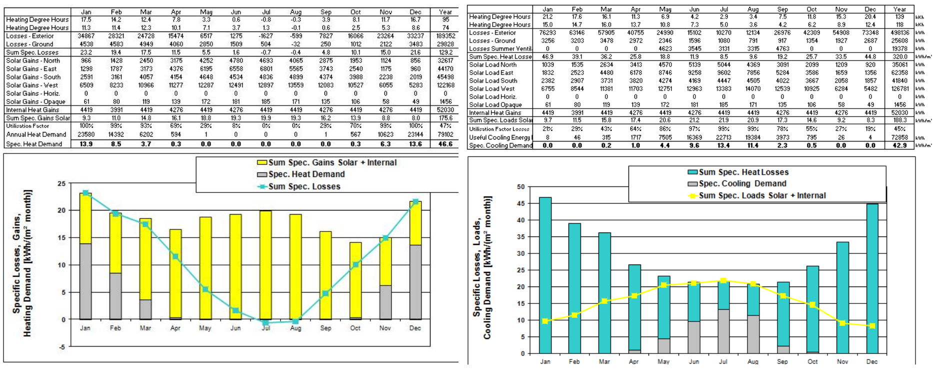


Fig. 4 – Inclination angle required monthly determined by using the graphical method

Table 1

Blades Inclination Angle, Required Monthly

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Solar radiation utilization factor [%]	100	100	96	77	33	10	0	0	31	78	99	100
Necessary shading [%]	0	0	4	23	67	90	100	100	66	22	1	0
Inclination angle	-15°	-18°	-21°	-15°	5°	13°	29°	37°	15°	-7°	-9°	-10°



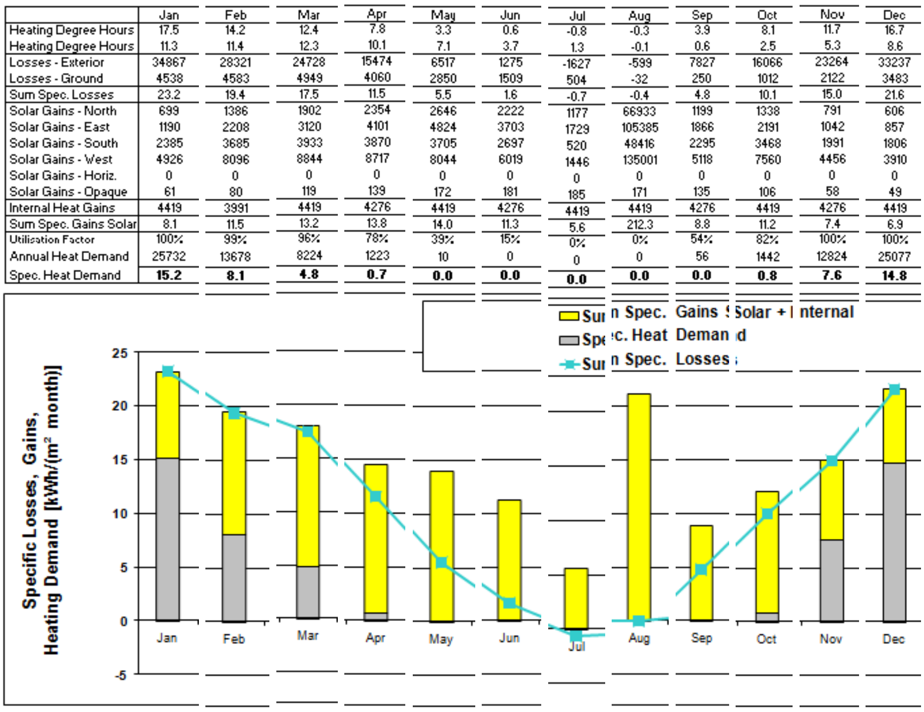
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heating Degree Hours	17.5	14.2	12.4	7.8	3.3	0.6	-0.8	-0.3	3.9	8.1	11.7	16.7	95
Heating Degree Hours	11.3	11.4	12.3	10.1	7.1	3.7	1.3	-0.1	0.6	2.5	5.3	8.6	74
Losses - Exterior	34867	28321	24728	15474	6517	1275	-1627	-599	7827	16066	23264	33237	189352
Losses - Ground	4538	4583	4949	4060	2850	1509	504	-32	250	1012	2122	3483	29828
Sum Spec. Losses	23.2	19.4	17.5	11.5	5.5	1.6	-0.7	-0.4	4.8	10.1	15.0	21.6	129.2
Solar Gains - North	966	1428	2450	3175	4252	4780	4693	4065	2875	1953	1124	856	32617
Solar Gains - East	1298	1787	3173	4376	6195	6558	6801	5565	3743	2540	1175	960	44170
Solar Gains - South	2591	3161	4057	4154	4648	4534	4836	4899	4374	3988	2238	2019	45498
Solar Gains - West	6509	8233	10966	11277	12287	12491	12897	13559	12083	10527	6055	5283	122168
Solar Gains - Horiz.	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar Gains - Opaque	61	80	119	139	172	181	185	171	135	106	58	49	1456
Internal Heat Gains	4419	3991	4419	4276	4419	4276	4419	4419	4276	4419	4276	4419	52030
Sum Spec. Gains Solar	9.3	11.0	14.8	16.1	18.8	19.3	19.9	19.3	16.2	13.9	8.8	8.0	175.6
Utilisation Factor	100%	99%	93%	69%	29%	8%	0%	0%	29%	70%	99%	100%	47%
Annual Heat Demand	23580	14392	6202	594	1	0	0	0	1	567	10623	23144	79102
Spec. Heat Demand	**13.9**	**8.5**	**3.7**	**0.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.3**	**6.3**	**13.6**	**46.6**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating Degree Hours	21.2	17.6	16.1	11.3	6.9	4.2	2.9	3.4	7.5	11.8	15.3	20.4	139	kKh
Heating Degree Hours	15.0	14.7	16.0	13.7	10.8	7.3	5.0	3.6	4.2	6.2	8.9	12.4	118	kKh
Losses - Exterior	76293	63146	57905	40755	24990	15102	10270	12134	26976	42309	54908	73348	498136	kWh
Losses - Ground	3256	3203	3478	2972	2346	1596	1080	791	917	1354	1927	2687	25608	kWh
Losses Summer Ventil.	0	0	0	0	4623	3545	3131	3315	4763	0	0	0	19378	kWh
Sum Spec. Heat Losse	46.9	39.1	36.2	25.8	18.8	11.9	8.5	9.6	19.2	25.7	33.5	44.8	320.0	kWh/m²
Solar Load North	1039	1535	2634	3413	4570	5139	5044	4369	3091	2099	1209	920	35061	kWh
Solar Load East	1832	2523	4480	6178	8746	9258	9602	7856	5284	3586	1659	1356	62358	kWh
Solar Load South	2382	2907	3731	3820	4274	4169	4447	4505	4022	3667	2058	1857	41840	kWh
Solar Load West	6755	8544	11381	11703	12751	12963	13383	14070	12539	10925	6284	5482	126781	kWh
Solar Load Horiz.	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solar Load Opaque	61	80	119	139	172	181	185	171	135	106	58	49	1456	kWh
Internal Heat Gains	4419	3991	4419	4276	4419	4276	4419	4419	4276	4419	4276	4419	52030	kWh
Sum Spec. Loads Solar	9.7	11.5	15.8	17.4	20.6	21.2	21.9	20.9	17.3	14.6	9.2	8.3	188.3	kWh/m²
Utilisation Factor Losses	21%	29%	43%	64%	86%	97%	99%	99%	78%	55%	27%	19%	45%	
Useful Cooling Energy	8	46	315	1717	7505	16369	22713	19384	3973	795	26	4	72858	kWh
Spec. Cooling Demand	**0.0**	**0.0**	**0.2**	**1.0**	**4.4**	**9.6**	**13.4**	**11.4**	**2.3**	**0.5**	**0.0**	**0.0**	**42.9**	kWh/m²

a *b*

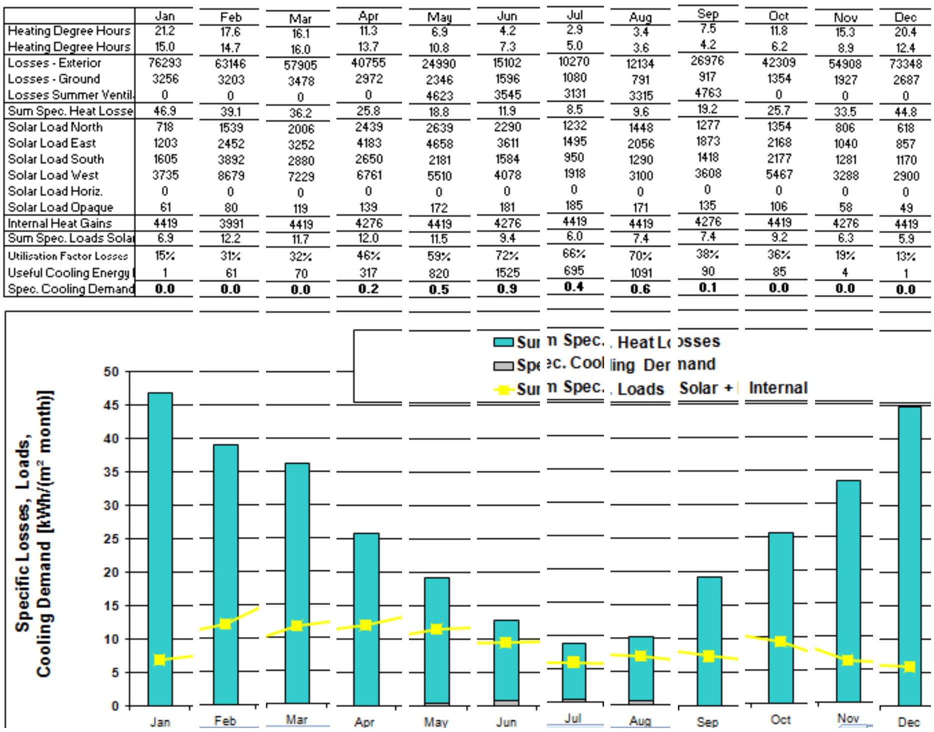
Fig. 5 – Evaluation of energy demand for: *a* – heating; *b* – cooling with the existing (fixed) shading system.

The results in the case with mobile shading system show a heating energy demand (Fig. 6) with 10.38% higher compared to the results obtained for the existing building (Fig. 5 *a*), as the solar radiation is partially blocked.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Heating Degree Hours	17.5	14.2	12.4	7.8	3.3	0.6	-0.8	-0.3	3.9	8.1	11.7	16.7
Heating Degree Hours	11.3	11.4	12.3	10.1	7.1	3.7	1.3	-0.1	0.6	2.5	5.3	8.6
Losses - Exterior	34867	28321	24728	15474	6517	1275	-1627	-599	7827	16066	23264	33237
Losses - Ground	4538	4583	4949	4060	2850	1509	504	-32	250	1012	2122	3483
Sum Spec. Losses	23.2	19.4	17.5	11.5	5.5	1.6	-0.7	-0.4	4.8	10.1	15.0	21.6
Solar Gains - North	699	1386	1902	2354	2646	2222	1177	66933	1199	1338	791	606
Solar Gains - East	1190	2208	3120	4101	4824	3703	1729	105385	1866	2191	1042	857
Solar Gains - South	2385	3685	3933	3870	3705	2697	520	48416	2295	3468	1991	1806
Solar Gains - West	4926	8096	8844	8717	8044	6019	1446	135001	5118	7560	4456	3910
Solar Gains - Horiz.	0	0	0	0	0	0	0	0	0	0	0	0
Solar Gains - Opaque	61	80	119	139	172	181	185	171	135	106	58	49
Internal Heat Gains	4419	3991	4419	4276	4419	4276	4419	4419	4276	4419	4276	4419
Sum Spec. Gains Solar	8.1	11.5	13.2	13.8	14.0	11.3	5.6	212.3	8.8	11.2	7.4	6.9
Utilization Factor	100%	99%	96%	78%	39%	15%	0%	0%	54%	82%	100%	100%
Annual Heat Demand	25732	13678	8224	1223	10	0	0	0	56	1442	12824	25077
Spec. Heat Demand	**15.2**	**8.1**	**4.8**	**0.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.8**	**7.6**	**14.8**

Fig. 6 – Evaluation of the heating energy demand – the building with mobile shading system.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Heating Degree Hours	21.2	17.6	16.1	11.3	6.9	4.2	2.9	3.4	7.5	11.8	15.3	20.4
Heating Degree Hours	15.0	14.7	16.0	13.7	10.8	7.3	5.0	3.6	4.2	6.2	8.9	12.4
Losses - Exterior	76293	63146	57905	40755	24990	15102	10270	12134	26976	42309	54908	73348
Losses - Ground	3256	3203	3478	2972	2346	1596	1080	791	917	1354	1927	2687
Losses Summer Ventil.	0	0	0	0	4623	3545	3131	3315	4763	0	0	0
Sum Spec. Heat Losse	46.9	39.1	36.2	25.8	18.8	11.9	8.5	9.6	19.2	25.7	33.5	44.8
Solar Load North	718	1539	2006	2439	2639	2290	1232	1448	1277	1354	806	618
Solar Load East	1203	2452	3252	4183	4658	3611	1495	2056	1873	2168	1040	857
Solar Load South	1605	3892	2880	2650	2181	1584	950	1290	1418	2177	1281	1170
Solar Load West	3735	8679	7229	6761	5510	4078	1918	3100	3608	5467	3288	2900
Solar Load Horiz.	0	0	0	0	0	0	0	0	0	0	0	0
Solar Load Opaque	61	80	119	139	172	181	185	171	135	106	58	49
Internal Heat Gains	4419	3991	4419	4276	4419	4276	4419	4419	4276	4419	4276	4419
Sum Spec. Loads Solar	6.9	12.2	11.7	12.0	11.5	9.4	6.0	7.4	7.4	9.2	6.3	5.9
Utilisation Factor Losses	15%	31%	32%	46%	59%	72%	66%	70%	38%	36%	19%	13%
Useful Cooling Energy	1	61	70	317	820	1525	695	1091	90	85	4	1
Spec. Cooling Demand	**0.0**	**0.0**	**0.0**	**0.2**	**0.5**	**0.9**	**0.4**	**0.6**	**0.1**	**0.0**	**0.0**	**0.0**

Fig. 7 – Evaluation of cooling energy demand – the building with mobile shading system.

Instead, the cooling energy demand drops with 93.72% (Fig. 7, Table 2). Moreover, if the total closure of wooden blades during the cold nights is considered, the heat losses can be reduced with 28.70% (Table 3). Consequently, a net reduction with 19.58% of the heating energy demand can also be observed between the two cases: existing fixed shading system or mobile shading system.

If the wooden blades are insulated with 5 mm aerogel, the heat losses are reduced with 22.4 kWh/m^{2}year, resulting in a saving of 37.02% (Table 4).

Table 2

Blades Inclination Angle, Required Monthly

	Heating energy demand, [kWh/m^{2}year]		Cooling energy demand, [kWh/m^{2}year]	
Existing (fixed) shading system	47.00	100%	43.00	100%
Mobile shad.syst. with wooden blades	52.00	+10.38%	2.70	–93.72%
Wooden blades that close at night	37.08	–19.58%		
Aerogel insulated wooden blades	29.60	–37.02%		

Table 3

The Reduction in Heat Losses by Closing the Wooden Blades During the Night

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Tot.
Sunlight hours [h]	8.90	10.28	11.83	13.58	15.05	15.88	15.55	14.25	12.60	10.93	9.36	8.53	
Heat losses through ground [kWh]	4538	4538	4949	4060	2850	1509	504	-32	250	1012	2122	3483	
Specific heat losses without shad. syst. [kWh/m^2] **(P1)**	23.20	19.40	17.50	11.50	5.50	1.60	-0.70	-0.40	4.80	10.10	15.00	21.60	129.10
Heat losses towards exterior without shad. syst. [kWh]	34867	28321	24728	15474	6517	1275	-1627	-599	7827	16066	23264	33237	
Heat losses towards exterior with closed blades [kWh]	26602	21619	18893	11837	5012	1011	-1196	-415	5996	12273	17753	25360	
Heat losses toward exterior with closed blades during night[kWh]	29666.94	24489.69	21769.17	13894.94	5955.76	1185.68	-1475.25	-524.25	6957.27	14000.40	19902.29	28159.62	
Specific heat losses with mobile shading system [kWh/m^2] **(P2)**	20.16	17.11	15.74	10.58	5.19	1.59	-0.57	-0.33	4.25	8.85	12.98	18.65	114.20
Energy savings in specif. heat loss by closing the blades during cold nights [kWh/m^2]**(P3=P1-P2)**	3.044	2.295	1.756	0.920	0.311	0.012	-0.128	-0.072	0.553	1.254	2.022	2.954	14.920

3. Replacement of Initial Glazing with ETFE Air Cushions (2nd Hypothesis)

The building energy performance is recalculated, considering that glazed surface is replaced by four-chamber ETFE air cushions that can inflate or deflate to optimize the heating and cooling energy demand. Simulations are made in which the value of the thermal transmittance *U* and the solar energy transmittance for the transparent elements can vary depending on the conditions of the interior and exterior environment. Thus, in the PHPP programme, separate calculations are performed for the cases where the ETFE system has:

A. four air chambers: U = 1.5 W/m^{2}K and g = 0.71 (in this scenario the envelope has minimal thermal transmittance providing better thermal insulation for winter and maximum solar energy transmission for maximum intake of solar radiation when heating of the indoor space is needed);

B. one air chamber: $U = 2$ W/m^{2}K and $g = 0.22$ (in this scenario the envelope system has moderate thermal transmittance and minimum solar energy transmission factor to limit overheating periods in summer days);

Table 4

The Reduction of Heat Losses by Closing the Wooden Blades Insulated with Aerogel During the Night

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Tot.
Sunlight hours [h]	8.90	10.28	11.83	13.58	15.05	15.88	15.55	14.25	12.6	10.93	9.36	8.53	
Heat losses through ground [kWh]	4538	4538	4949	4060	2850	1509	504	-32	250	1012	2122	3483	
Specific heat losses without shad. syst. [kWh/m^2] **(P1)**	23.2	19.4	17.5	11.5	5.5	1.6	-0.7	-0.4	4.8	10.1	15.0	21.6	129.1
Heat losses towards exterior without shad. syst. [kWh]	34867	28321	24728	15474	6517	1275	-1627	-599	7827	16066	23264	33237	
Heat losses towards exterior with closed blades [kWh]	22470	18268	15975	10018	4259	879	-981	-323	5080	10376	14997	21421	
Heat losses toward exterior with closed blades during night[kWh]	27067.22	22574.04	20289.50	13105.19	5674.95	1141.02	-1399.55	-486.875	6522.17	12967.32	18221.13	25620.60	
Specific heat losses with mobile shading system [kWh/m^2] **(P2)**	18.620	15.976	14.872	10.115	5.024	1.562	-0.528	-0.306	3.900	8.238	11.988	17.150	106.710
Energy savings in specif. heat loss by closing the blades during cold nights [kWh/m^2]**(P3=P1-P2)**	4.576	3.424	2.628	1.385	0.476	0.038	-0.172	-0.094	0.809	1.862	3.012	4.450	22.390

C. airless chambers: $U = 5.6$ W/m^{2}K and $g = 0.22$ (in this scenario the envelope system has maximum thermal transmittance during the summer nights, to eliminate the heat accumulated during the day).

Table 5

Heating and Cooling Energy Demand in Case of A&B Scenario

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Scenario A	6.93	3.0	0.7	1.1	5.7	11.2	14.6	12.8	3.2	0.5	1.9	7.0
Scenario B	19.10	14.8	11.4	5.0	0.3	0.6	1.6	1.1	0.2	4.2	10.8	17.9
Scenario A&B	6.93	3.0	0.7	1.1	0.3	0.6	1.6	1.1	0.2	0.5	1.9	7.0

Analyzing the monthly energy demand for heating and cooling for both, A and B scenarios and choosing the lowest value, the time intervals for activating each scenario are determined (Table 5). Thus, for the period of October-April, scenario A (ETFE cushions with 4 air chambers) was selected and for May-September - scenario B (ETFE cushions with one air chamber). In the case of the combined scenarios A and B, the building energy demand obtained for heating and cooling was 24.93 kWh/m^{2}year is, of which:

– heating energy demand: 19.3 kWh/m^{2}year;

– cooling energy demand: 5.63 kWh/m^{2}year.

Table 6

Energy Savings in Cooling Energy Demand by Adding Scenario C to A&B Scenario

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Heat losses towards exterior [kWh]	123,324	102,046	93,540	65,810	40,310	24,334	16,506	19,527	43,561	68,365	88,754	118,563
Heat losses tr. ground [kWh]	3256	3203	3478	2972	2346	1596	1080	791	917	1354	1927	2687
Specific heat losses by total deflation of the air cushions [kWh/m^2]	74.59	62.02	57.17	40.53	25.14	15.28	10.36	11.97	26.21	41.08	53.44	71.45
Specific heat losses by applying scenario A&B [kWh/m^2]	38.5	32.2	29.8	23.4	8.3	8.5	8.7	8.4	7.2	23.1	27.5	36.7
Specific heat losses in addition by total deflation of the air cushions [kWh/m^2]	36.09	29.82	27.37	17.13	16.84	6.78	1.66	3.57	19.01	17.98	25.94	34.75
Cooling energy demand by applying scenario A & B [kWh/m^2]	0.0	0.0	0.2	1.0	0.1	0.6	1.6	1.1	0.0	0.5	0.0	0.0
Energy savings in cooling energy demand by applying scenario C [kWh/m^2]	0.0	0.0	0.2	1.0	0.1	0.6	1.6	1.1	0.0	0.5	0.0	0.0

In the case of total air cushions deflation during summer nights (scenario C), heat losses through the façade during summer nights increase (Table 6), the cooling energy demand decreasing to 5.1 kWh/m^{2}year, a 90% reduction compared to the combined scenarios A & B.

By combining the scenarios A, B and C, the values of energy demand are:

– 19.3 kWh/m^{2}year for heating;
– 0.53 kWh/m^{2}year for cooling.

Thus, by replacing the initial glazing with a four-chamber ETFE air cushion system in October-March (scenario A, which confers higher thermal resistance to the transparent surfaces of the envelope) and respectively with a single air chamber ETFE in April-September (scenario B) with the possibility of total deflation during the summer nights (scenario C, which allows releasing the heat from the indoor space to the exterior), the heating energy demand decreases by 58.94% and the cooling energy demand by 98.77% (Table 7).

Table 7
Heating and Cooling Energy Demand in Case of A&B&C Scenario

	Heating energy demand [kWh/m^{2}year]	Cooling energy demand [kWh/m^{2}year]
Initial	47.00	43.00
Scenario A&B	19.30	5.63
Scenario A&B&C	19.30	0.53
Comparison to initial results	–58.94%	–98.77%

4. Integration of Renewable Energy Sources (3rd Hypothesis)

4.1. Mobile Shading System with PV Panels

SolarPro software was used to calculate the amount of energy collected by integrating photovoltaic panels into the horizontal elements of the shading system on the South-Western and South-Eastern office building façades. PV panels and the blades have the same declivity angle (Table 1), but not less than 1°. Solar-Fabrik photovoltaic panels SF 125-120 were selected from the programme database, with dimensions of 1.485 / 0.663 m and 120W capacity. This type was chosen to sum up a width as close as possible to the required one of 1.45m (Fig. 8), with the highest capacity. On the glazed surface of each floor on the South-Western façade, the system is arranged in a two-rows configuration, having 3 to 24 columns of photovoltaic modules (depending on the glazing width), with the following dimensions:

– height: 2 × 0.663 = 1.326 m;
– variable width: between 3 × 1,485 = 4,455 m and 24 × 1,485 = 35.64 m.

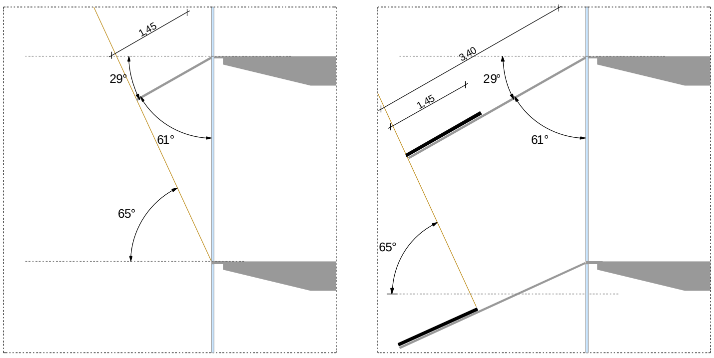


Fig. 8 – Design of the geometry of PV panels integrated within the mobile shading system.

The resulting energy production is of 9 443.28 kWh/year on the South-Western façade and 2,642.26 kWh/year on the South-Eastern façade (Table 8), totaling 12,085.54 kWh/year.

Table 8
Monthly Energy Collection According to the PV Panels Inclination Angle

	Inclination angle [°]	AC energy S-V [kWh]	AC energy S–E [kWh]
Jan.	1	388.32	110.28
Feb.	1	502.95	144.87
Mar.	1	779.46	222.73
Apr.	1	916.34	256.82
May	5	1136.75	311.50
Jun.	13	1166.85	320.30
Jul.	29	1206.42	330.20
Aug.	37	1176.04	327.49
Sept.	15	949.87	270.35
Oct.	1	612.41	176.70
Nov.	1	328.26	92.88
Dec.	1	279.61	78.12
Tot.		9 443.28	2 642.26

Considering that 33 Solar-Fabrik photovoltaic panels SF 125-120, inclined at 45° and facing South to achieve maximum efficiency, can be installed on the rooftop terrace, the amount of solar energy collected yearly increases by 4,255.79 kWh/year, thus reaching 16,341.33 kWh/year in total.

The energy produced by PV panels can save 9.63 kWh/m^{2}year in energy demand for heating and cooling. Total energy demand for cooling and heating decreases with 29.81% (Table 9).

Table 9

Heating and Cooling Energy Demand in Case of Integrating PV Panels

	Heating energy demand [kWh/m^{2}year]	Cooling energy demand [kWh/m^{2}year]	Total [kWh/m^{2}year]
Initial data	47.00	43.00	90.00
Adjustable aerogel insulated wooden blades	29.60	2.70	32.30
Integrated PV panels	19.97	2.70	22.67

4.2. ETFE Air Cushions with PV Cells

Taking into account the monthly shading requirement, choosing for the solar energy transmission factor the maximum value for October-April (g = = 0.71) and the minimum value for May-September (g = 0.2), which can be changed by inflation and deflation of an air cushion whose membranes integrate PV cells, the energy collected for each calculation period from the South-Western and South-Eastern façades is calculated. The PV cells placement is considered to cover 0.29% and respectively 0.8% of the membrane area, the angle of inclination being 90° (i.e. in the façade plane).

The energy collected annually is 10,495.76 kWh – Table 10 (7,423.3 kWh for the South-Western façade and 3,072.46 kWh for the South-Eastern façade), reducing the energy demand for heating and cooling by 6.2 kWh/m^{2}year. Thus, the total heating and cooling demand decreases from 19.83 kWh/m^{2}year to 13.63 kWh/m^{2}year (31.26%).

Table 10

Energy Collected Monthly by the PV Cells on ETFE Air Cushions on SW and SE Façades

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Tot.
Surface, [%]	0.29	0.29	0.29	0.29	0.80	0.80	0.80	0.80	0.80	0.29	0.29	0.29	
AC energy SW, [kWh]	495.75	519.23	67.20	688.78	779.67	764.89	783.57	780.34	711.72	582.57	31.27	325.31	7423.30
AC energy SE, [kWh]	224.13	227.10	28.90	279.64	307.11	296.38	305.97	313.50	296.82	251.73	13.95	146.23	3072.46

5. Comparison of Fixed and Mobile Shading Systems – Conclusions

In order to formulate a series of practical conclusions sustained by the theoretical ones, simulations were made considering the 3D building model and the data of the real “Centris” building. The results obtained for the energy performance are shown in Table 11:

– the optimal solution is to use ETFE air-cushioned PV cells for transparent envelope surfaces: 13.63 kWh/m^{2}year heating and cooling energy demand, representing 14.78 % of the total heating and cooling energy demand of the existing building;

– integration of a mobile shading system with PV panels is reducing the energy demand by 66.48%.

Table 11

Annual Energy Demand for ”Centris” Office Building – Analyzed Solutions

	Static envelope (as built)	Mobile shading syst. with wooden blades	Mobile shad. system with blades insulated with aerogel	ETFE air cushions	Mobile shading system with PV panels	ETFE air cushions with PV cells
Heating energy demand [kWh/m^{2}year]	47.00	37.10	29.60	19.30	27.47	13.10
Cooling energy demand [kWh/m^{2}year]	43.00	2.70	2.70	0.53	2.70	0.53
Total energy demand [kWh/m^{2}year]	90.00	39.80	32.30	19.83	30.17	13.63

To make a comparison between fixed and mobile shading systems, the 3D model and the data of the existing building are introduced into the Design Builder programme that allows simulations with dynamic envelope systems.

Four alternatives are considered for the building:

– *without shading systems* (**A**);

– with *fixed shading system* consisting of 50 mm thick wooden blades, 85 cm deep, inclined at 30^o, spaced 85 cm vertically, emissivity factor 0.9, solar absorption 0.78 (**B**);

– with a *mobile shading system* with 1 mm thick blades, inclined at 45°, spaced 20 cm vertically, emissivity factor 0,9, mean reflectivity 0,5; the system is activated when the *internal temperature exceeds 24° C* (**C**);

– with a *mobile shading system* with 1 mm thick blades, inclined at 45°, spaced 20 cm vertically, emissivity 0.9, average reflectivity 0.5, thermal conductivity 0.9 W/mK; the system is activated when the *interior space overheats and closes on the cold nights of winter* (**D**).

The room with the largest South-Western glazed surface (of 14.06 m^2), is analyzed taking into account the significant solar input. In this respect, the variation of solar radiation transmitted through the glass (Fig.9), as well as the heat input through the glazing are analyzed.

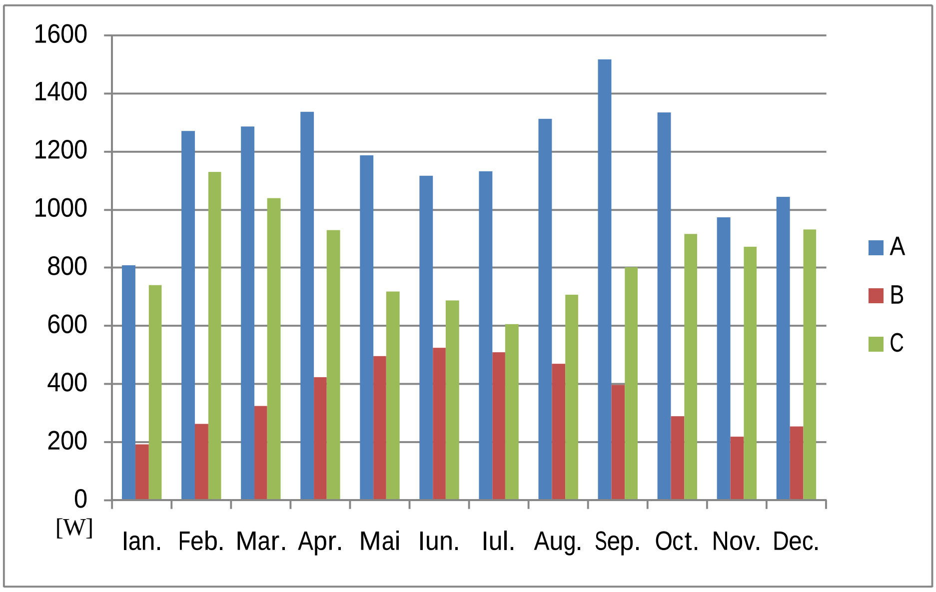


Fig. 9 – The solar radiation graph for the glazed surface in scenarios A, B and C.

For the glazed surface with the widest area (i.e. 14.06 m^2), the maximum solar radiation is reached in September in **scenario A** (Table 12). By applying the fixed shading system (**scenario B**), the solar radiation drops by 73, 93% in September and by 76.20% in January. **Scenario C** highlights the activation of the shading system for 1454.5 h/year, *i.e.* when the indoor temperature exceeds 24^{o}C. The maximum solar radiation across the glazing is reached in February and the lowest in July (46.66% lower compared to Scenario A – with no shading system). Compared to scenario A, cooling energy demand decreases by 37.04%. In **Scenario D**, the shading system is activated 2040.5 h/year; the values of the solar radiation penetrating inside are equal to those in scenario C. As compared to Scenario C, by closing the shading system during the night, the heating energy demand decreases by 24 %.

Table 12

Maximum and Minimum Solar Radiation for Scenarios A, B and C

	Maximum solar radiation		Minimum solar radiation	
	[W]	Month	[W]	Month
Scenario A	1518.05	Sep.	808.32	Ian.
Scenario B	523.92	Jun.	192.35	Ian.
Scenario C	1129.90	Feb.	604.35	Jul.

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CLĂDIRE DE BIROURI CU ANVELOPĂ ADAPTABILĂ LA MEDIU
Studiu de caz

(Rezumat)

Lucrarea compară performanța energetică a unei clădiri de birouri existente – Centrul „Centris” din orașul Iași – luând în considerare mai multe soluții pentru anvelopa clădirii. Anvelopa statică existentă este modificată succesiv prin instalarea unor seturi de soluții dinamice după cum urmează: 1) sistem de umbrire mobilă cu lame reglabile din lemn, cu sau fără izolație (aerogel), care satisface necesarul de umbrire, 2) inlocuirea vitrajului existent cu perne de aer ETFE cu 4 camere care se pot umfla sau dezumfla după anumite perioade calculate, 3) integrarea unor panourilor PV în sistemul de umbrire mobilă şi unor celule PV în pernele de aer ETFE. Rezultatele arată că soluția optimă este utilizarea pernelor de aer ETFE cu celule PV pentru suprafețele transparente ale anvelopelor, reducând astfel necesarul de energie pentru încălzire şi răcire cu 85,22% față de clădirea existentă. De asemenea, prin integrarea unui sistem mobil de umbrire cu panouri PV, necesarul de energie este redus cu 66,48%.