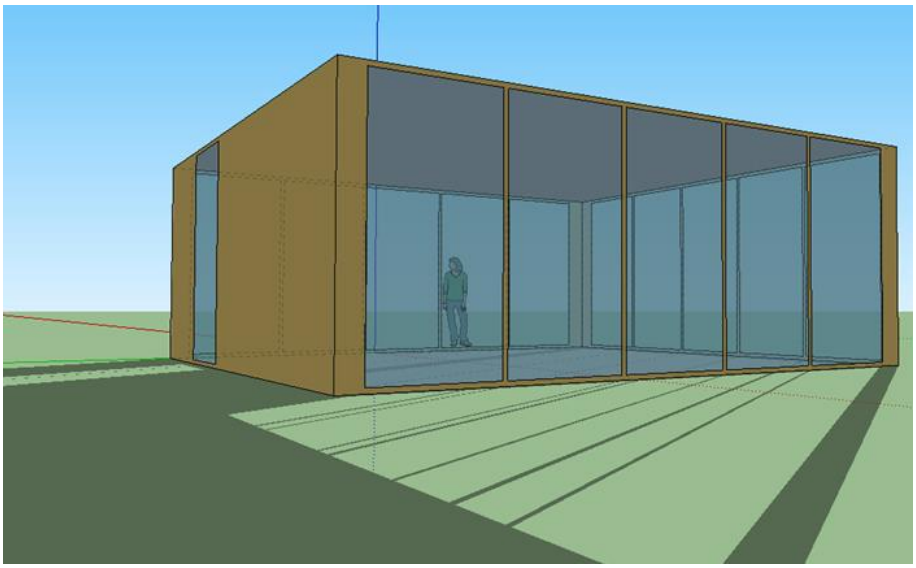
Case study for Bulgarian- and Spain-Demo-sites, different variants of façade



This document represents a report in WP1:
Façade design & building simulation

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INDUSTRIAL DEVELOPMENT OF WATER-FLOW GLAZING SYSTEMS

Collaborative Project - Grant Agreement No. 680441 Small or medium-scale focused research project, H2020-EE-2015-1-PPP

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D – 1.2 CASE STUDY FOR BULGARIAN– AND SPAIN DEMO-SITES, DIFFERENT VARIANTS OF FACADE		
Due date	Month 12	
Author(s)	Benito Lauret and Belén Pérez-Pujazón (UPM-ETSAM)	
Workpackage No. and Leader	WP 1 and B+G	
Date released by WP leader	July 2016	
Date released by Coordinator		
DISSEMINATION LEVEL		
PU	*Public*	**x**
PP	*Restricted to other program participants (including the Commission Services)*	
RE	*Restricted to a group specified by the consortium (including the Commission Services)*	
CO	*Confidential, only for members of the consortium (including the Commission Services)*	
NATURE OF THE DELIVERABLE		
R	*Report*	**x**
P	*Prototype*	
D	*Demonstrator*	
O	*Other*	

SUMMARY	
Keywords	Simulation, IDA-ICE, Energy Plus, Demonstrator, Pavilion, Façade, Demo-site
Abstract	Several simulations for two versions of a Bulgarian Demonstrator have been carried out with the IDA-ICE and Energy Plus programs. In both versions two different arrangements of the façade have been considered. Equally one version (current version) of a/the Spanish demonstrator has also been simulated with Energy Plus. The results show the advantages of using FFG in glazed façades as regards energy consumption, thus achieving zero energy performance is feasible. Associated costs could also be estimated taking into account both the FFG glazed surface and energy savings.

HISTORY			
Author	**Date**	**Related to WP/Task**	**Comments**
Benito Lauret, Belén Pérez-Pujazón (UPM-ETSAM)	July 2016	WP-1 Façade design & building simulation/Task 1.2. Simulation of dynamic interaction, at building level	

1. Content of Deliverable

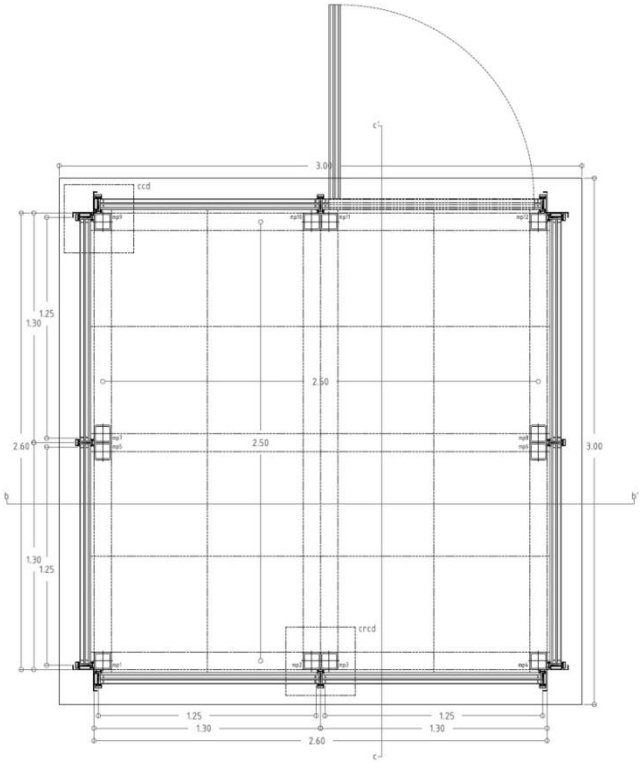
This deliverable contains energy simulations for two versions of the BULGARIAN Pavilion in the Sofia Tech Park, in accordance with the drawings and specifications supplied by Architectonika.

It is formerly related to Task 1.2. (Simulation of dynamic interaction, at the building level) and is related to the WP-6 Demonstrators, since the simulation models are based on Demonstrators layouts. Two generations of Bulgarian demonstrators have been developed to date, both of which have been simulated. The first one was simulated with the IDA-ICE program in two

versions: 75% glazed façade and 50% glazed façade. The second one, designed in June 2016, has been simulated with Energy Plus for easier and quicker results. In the same way, a simulation an Energy Plus simulation has also been carried out in Spanish demonstrator.

A. Spanish Demonstrator Design

The Spanish demonstrator will be located on the Montegancedo campus of the Technical University of Madrid, with access from the northeast. Its exterior dimensions are 3.00x3.00x3.70 meters.
The structure is based on hollow steel tubular profiles. The envelope of the demonstrator is made of active glass modular units with an aluminum frame. The slab floor and the roof consist of a steel mesh and sandwich panel (steel/foam/steel). The foundations are made of prefabricated, pre-stressed slab type concrete blocks.



IMAGES 01, 02:
PLANT OF SPANISH DEMONSTRATOR IN MONTEGANCEDO CAMPUS, MADRID

Model Characteristics

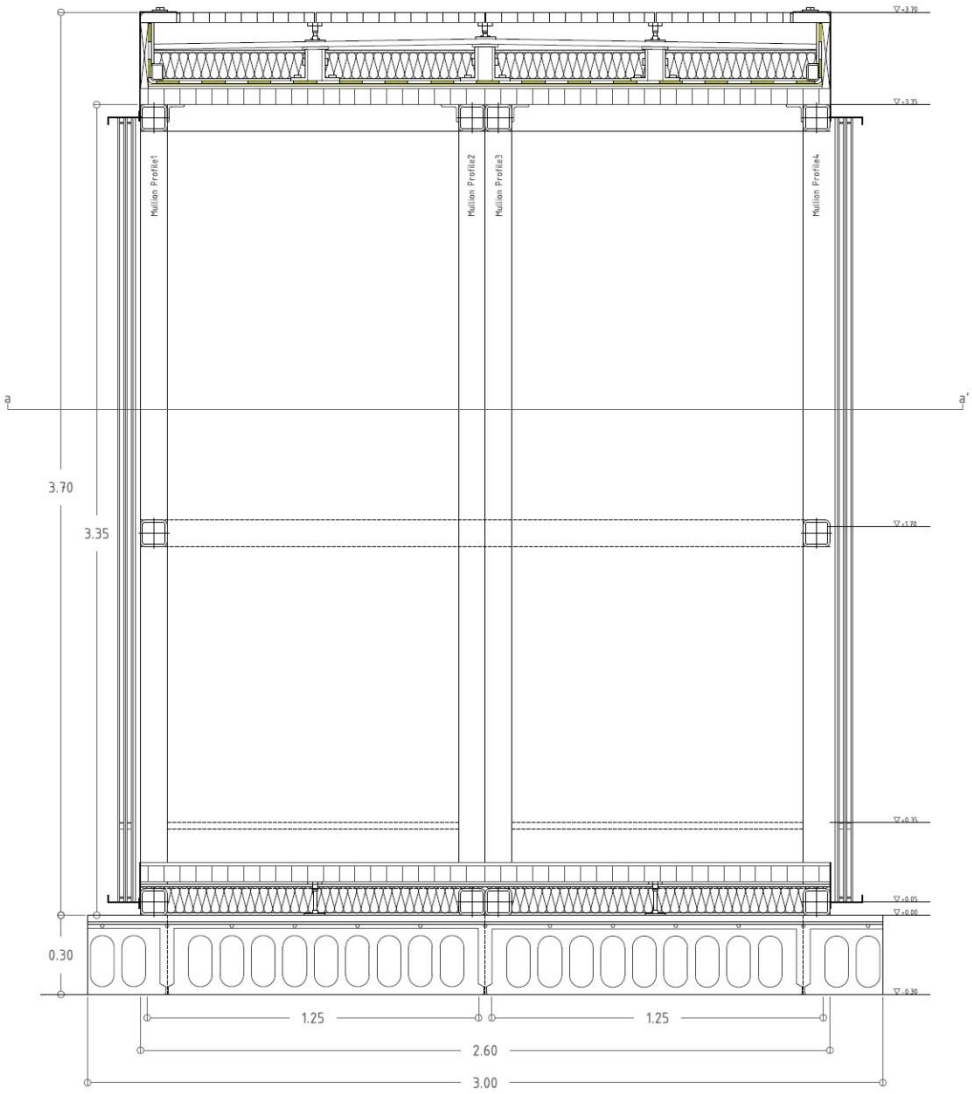


IMAGE 04: LONGITUDINAL SECTION OF SPANISH DEMONSTRATOR

ENVELOPE MATERIALS:

The table below describes the constructive composition of the floor, the roof, and the façades of the demonstrator exposed to external environment, together with its thickness (cm), surface (m²) and thermal transmittance U (W/m²K).

FLOOR	THICKNESS [cm]	U-FACTOR [W/m²-K]	AREA [m²]
Tramex 6 cm + Sheet metal 0.04 cm + Extruded polystyrene 9.02 cm + Sheet metal 0.04 cm + Concrete slab 30 cm	46.00	0.460	7.00

ROOF	THICKNESS [cm]	U-FACTOR [W/m²-K]	AREA [m²]
Extruded polystyrene topcoat 3 cm + Air chamber 6 cm + Sheet metal 0.04 cm + Extruded polystyrene 9.02 cm + Sheet metal 0.04 cm + Waterproofing layer 0.5 cm + Tramex 6 cm	25.50	0.310	7.00

FAÇADES	THICKNESS [cm]	U-FACTOR [W/m²-K]	AREA [m²]
Sheet metal 0.04 cm + Air chamber 9.02 cm + Sheet metal 0.04 cm	10.0	2.9	7.95

The table below summarizes the relationship between the windows and walls in the Spanish demonstrator.

WINDOW-WALL RATIO	Total	North (315 to 45 deg)	East (45 to 135 deg)	South (135 to 225 deg)	West (225 to 315 deg)
Gross Wall Area [m2]	31.80	7.95	7.95	7.95	7.95
Window Opening Area [m2]	29.00	7.25	7.25	7.25	7.25
Gross Window-Wall Ratio [%]	91.19	91.19	91.19	91.19	91.19

GLAZING:

According to the deliverable D–1.1., (First Generation of Site-ZEB Building Simulation with performance data of existing Water Flow Glazing), it is assumed that the active façade will use the iThermglass glazing configuration in Madrid.

Following the approach described in previous simulations, energy consumption due to Reference Glass (6 mm/16 mm (argon)/ 6 mm, with Cool-lite film ST150 on the inner face of the outer glass), is compared with the energy consumption obtained using iThermglass (10 + 4 mm/16 mm water chamber/ 4 + 10 mm / 16 mm argon / 4 + 4 mm, with Saflex R solar SG41 film on exterior glass an Saflex R standard RB11 in the middle and interior glass).

CLIMATIC CONDITIONS

ASHRAE weather data (IWEC) for Madrid is used , which is These are available on the Energy Plus official website (https://energyplus.net/weather). The table below shows the main weather parameters for Madrid:

Weather Statistics File

Reference	20140701-31_ESP_MADRIDEPW
Site: Location	MADRID - ESP
Latitude	{N 40° 27'}
Longitude	{W 3° 32'}
Time Zone	{GMT +1.0 Hours}

Elevation (m) above sea level	582
Standard Pressure at Elevation	94526Pa
Data Source	IWEC Data
WMO Station	082210
Weather File Design Conditions	Climate Design Data 2013 ASHRAE Handbook
Heating Design Temperature 99.6% (C)	-4°
Cooling Design Temperature 1% (C)	35.1°
Cooling Design Temperature 2% (C)	33.8°
Maximum Dry Bulb Temperature (C)	40.4°
Minimum Dry Bulb Temperature (C)	-4.6°
Minimum Dry Bulb Occurs on	Dec 23
Maximum Dew Point Temperature (C)	23.3°
Maximum Dew Point Occurs on	Aug 11
Standard Heating Degree-Days (base 10°C)	441
Weather File Heating Degree-Days (base 10°C)	446
Standard Cooling Degree-Days (base 18.3°C)	635
Weather File Cooling Degree-Days (base 18°C)	591
Köppen Classification	Cfa
Köppen Description	Humid subtropical (mild with no dry season, hot summer, lat. 20-35°N)
Köppen Recommendation	Unbearably hot dry periods in summer, but passive cooling is possible
ASHRAE Climate Zone	3C
ASHRAE Description	Warm-Marine

BUILDING USE

The building will be used for offices, with an opening schedule from 8:00 to 18:00, (Monday to Friday) and 8:00 to 14:00 on Saturdays.

INTERNAL LOADS

Following internal loads have been used for the simulations: (equipment loads: 7 W/m², lighting loads: 10 W/m², occupation loads: 5 W/m²).

CONDITIONING SYSTEM

The heat pump is the same as that in the Bulgarian demonstrator with a COP (Coefficient of Performance) of 3.21 and an EER (Energy Efficiency Ratio) of 3.…

TEMPERATURE SETTINGS

The temperatures set for winter and summer is 21° C and 25° C respectively.

SIMULATION CONDITIONS

To determine energy consumption in the building, Simulations have been carried out with Energy Plus. . The Open Studio Application Suite has been used for the graphical interface.

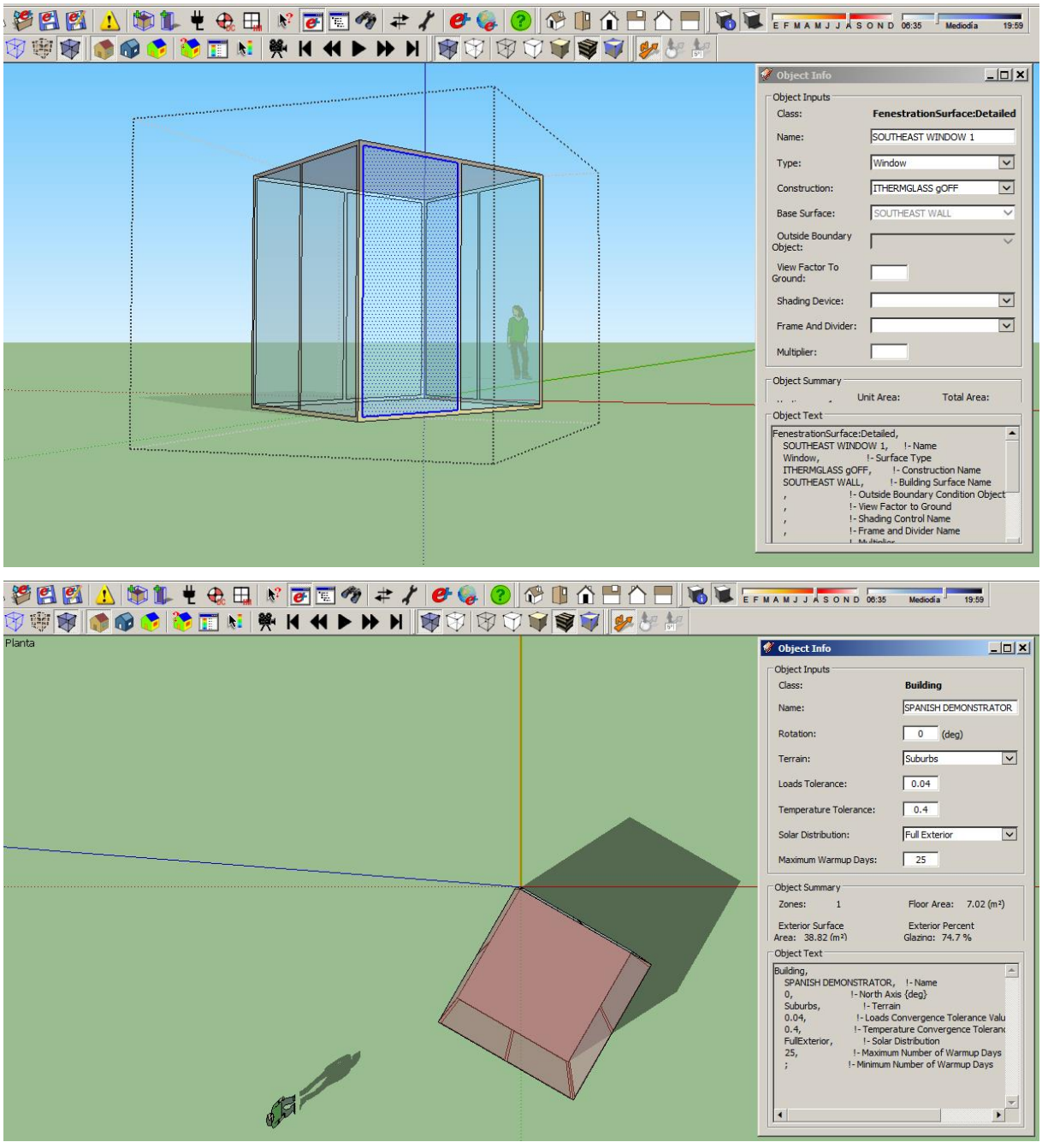


IMAGE 05, 06: SIMULATION OF DEMONSTRATOR IN MADRID WITH ENERGYPLUS SOFTWARE 8.4.1. , IMAGES RENDERED WITH OPENSTUDIO APLICATION SUITE PLATFORM

The g-ON and g-OFF values were set in accordance with previous simulations as follows:

From May to September iThermglass will be activated (with flow/g-ON) and from October to April the FFG element is inactive (without flow/gOFF). Annual results will be compared to those of the Reference Glass.

SIMULATION A: PASIVE GLAZING

PASIVE GLAZING (REFERENCE GLASS)	Area [m2]	U-Factor [W/m2-K]	g VALUE	Tvis	Parent Surface	Cardinal Direction
NORTHWEST WINDOW 2	3.6	1.1	0.431	0.46	NORTHWEST WALL	NW
NORTHWEST WINDOW 1	3.6	1.1	0.431	0.46	NORTHWEST WALL	NW
SOUTHWEST WINDOW 2	3.6	1.1	0.431	0.46	SOUTHWEST WALL	SW
SOUTHWEST WINDOW 1	3.6	1.1	0.431	0.46	SOUTHWEST WALL	SW
SOUTHEAST WINDOW 2	3.6	1.1	0.431	0.46	SOUTHEAST WALL	SE
SOUTHEAST WINDOW 1	3.6	1.1	0.431	0.46	SOUTHEAST WALL	SE
NORTHEAST DOOR	3.6	1.1	0.431	0.46	NORTHEAST WALL	NE
NORTHEAST WINDOW 2	3.6	1.1	0.431	0.46	NORTHEAST WALL	NE

SIMULATION B: ACTIVE GLAZING

ACTIVE GLAZING (ITHERMGLASS)	Area [m2]	U-Factor [W/m2-K]	g ON	gOFF	Tvis	Parent Surface	Cardinal Direction
NORTHWEST WINDOW 2	3.6	1.1	0.235	0.301	0.48	NORTHWEST WALL	NW
NORTHWEST WINDOW 1	3.6	1.1	0.235	0.301	0.48	NORTHWEST WALL	NW
SOUTHWEST WINDOW 2	3.6	1.1	0.235	0.301	0.48	SOUTHWEST WALL	SW
SOUTHWEST WINDOW 1	3.6	1.1	0.235	0.301	0.48	SOUTHWEST WALL	SW
SOUTHEAST WINDOW 2	3.6	1.1	0.235	0.301	0.48	SOUTHEAST WALL	SE
SOUTHEAST WINDOW 1	3.6	1.1	0.235	0.301	0.48	SOUTHEAST WALL	SE
NORTHEAST DOOR	3.6	1.1	0.235	0.301	0.48	NORTHEAST WALL	NE
NORTHEAST WINDOW 2	3.6	1.1	0.235	0.301	0.48	NORTHEAST WALL	NE

B. Sofia Demonstrator Design

The second (current) building design consists of another stand-alone pavilion, with a square geometry, as well as the previous design, and with a layout on a single story with dimensions of 7, 1x7, 11 m. It has a ceiling height of 2.7 m, with aan open office design. As in the previous design, three of the facades are fully glazed, from floor to ceiling, except the north façade. The glass façades are made of modules of glass with the same dimensions of 2.7 x 1.3 m.

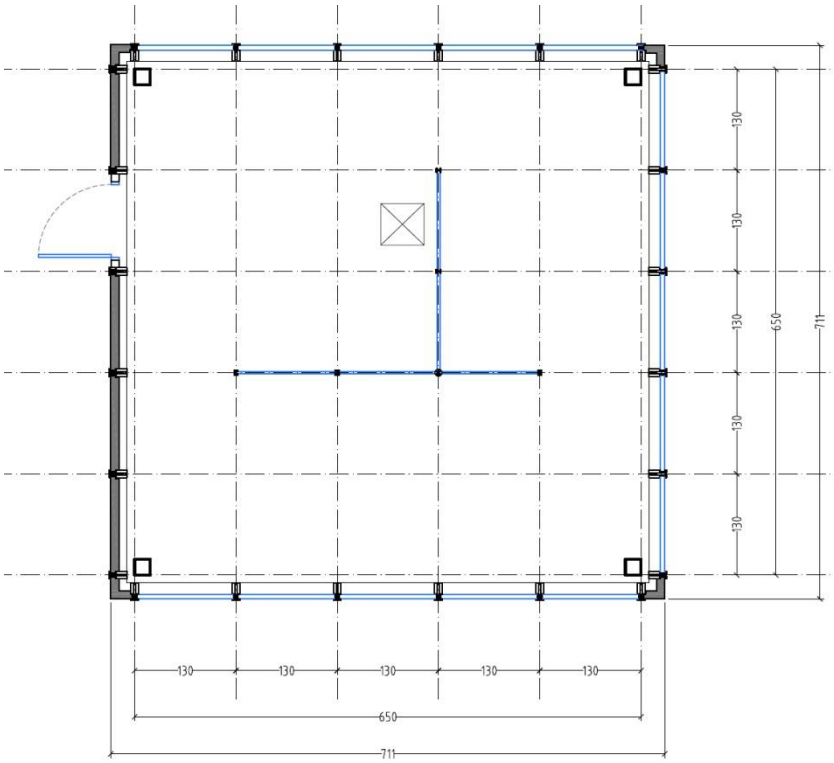


IMAGE 01: PLANT OF 2nd PAVILION DESIGN IN SOFIA

Model Characteristics

IMAGE 02, 03: IMAGES OF 2nd PAVILION DESIGN IN SOFIA

ENVELOPE MATERIALS

The second design has same constructive and dimensional properties of the building envelope elements.). The following table describes all envelope components:

FLOOR	THICKNESS [cm]	U-FACTOR [W/m²-K]	AREA [m²]
Flooring: PVC 0.4 cm +Chipboard 2 cm + Concrete slab 30 cm +Air Chamber 1 m	32.4 + 100	1.468	50.55

ROOF	THICKNESS [cm]	U-FACTOR [W/m²-K]	AREA [m²]
Sheet metal miniwave 0.04 cm + 15 cm air chamber + extruded polystyrene 6 cm + concrete slab 30 cm + 2 cm particleboard + sheet metal 0.04 cm finishing.	53.8	0.396	50.55

FAÇADES	THICKNESS [cm]	U-FACTOR [W/m²-K]	AREA [m²]
Sandwich Panel(Sheet metal 0.04 cm + Polyurethane 0.0392 cm)	4.0	0.677	21.0

Table below summarizes the window-to-wall ratios, walls and windows area:

WINDOW-WALL RATIO	Total	North (315 to 45 deg)	East (45 to 135 deg)	South (135 to 225 deg)	West (225 to 315 deg)
Gross Wall Area [m2]	75.60	18.90	18.90	18.90	18.90
Window Opening Area [m2]	52.00	3.25	16.25	16.25	16.25
Gross Window-Wall Ratio [%]	68.78	17.20	85.98	85.98	85.98

GLAZING

Energy consumption due to the use of passive glazing -Reference Glass (6 mm/16 mm (argon)/ 6 mm, with Cool-lite film ST150 on the inner face of the outer glass), is compared to the consumption obtained by installing the active façade- iThermglass (10 + 4 mm/16 mm water chamber/ 4 + 10 mm / 16 mm argon / 4 + 4 mm, with Saflex R solar SG41 film on the exterior glass, ad Saflex R standard RB11 in the middle and interior glass).

According to the previous document deliverable D–1.1. (First Generation of Site-ZEB Building Simulation with performance data from existing Water Flow Glazing) with a date of 01.02.2016, it is assumed that the active façade has the iThermglass configuration for Sofia. A variable g value, which works as if there were a flow in the glazing element (gON) or without any flow (gOFF)is also considered. Dynamic glass which corresponds to the location in Sofia is the iThermglass system. According to the document Reference Glazing Catalogue, the value of this glass g-value varies from between 0.235 (gON, with circulation of water) and 0.301 (gOFF, without any water circulation).

CLIMATIC CONDITIONS

The same climatic file supplied by ASHRAE (American Society of Heating Refrigerating and Air-Conditioning Engineers) has been used. It is available on the Energy Plus official website (https://energyplus.net/weather). Table below summarizes the main weather parameters contained.

Weather Statistics File

Reference	BGR_Sofia.156140_IWEC
Site: Location	SOFIA - BGR
Latitude	{N 42° 43'}
Longitude	{E 23° 22'}
Elevation (m) above sea level	595
Standard Pressure at Elevation	94378Pa
Weather File Design Conditions	2009 ASHRAE Handbook
Heating Design Temperature 99.6% (C)	-12.5°
Cooling Design Temperature 1% (C)	30°
Cooling Design Temperature 2% (C)	28.2°
Maximum Dry Bulb Temperature (C)	31.0°
Minimum Dry Bulb Temperature (C)	-14.0°
Minimum Dry Bulb Occurs on	Feb 2
Maximum Dew Point Temperature (C)	20.0°
Maximum Dew Point Occurs on	Jun 17
Standard Heating Degree-Days (base 10°C)	1318
Weather File Heating Degree-Days (base 10°C)	1260
Standard Cooling Degree-Days (base 18.3°C)	239
Weather File Cooling Degree-Days (base 18°C)	240
Köppen Classification	Dfb

BUILDING USE

The building will be used for offices, with an opening schedule from 8:00 to 18:00, (Monday to Friday) and 8:00 to 14:00 on Saturdays

INTERNAL LOADS

During scheduled hours of operation, the same level of internal loads considered in previous design (equipment loads: 7 W/m², lighting loads: 10 W/m², occupation loads: 5 W/m²) has been set.

CONDITIONING SYSTEM

It has been assumed that the building has a heat pump, with a COP (Coefficient of Performance) of 3.21 and an EER (Energy Efficiency Ratio) equivalent to 3.61.

TEMPERATURE SETTINGS

A comfort temperature value in winter of 21° C and a value of 25° C in summer has been set.

SIMULATION CONDITIONS

For performing the energy simulations, the EnergyPlus 8.4.1 (https://energyplus.net) programme tool has been used to calculate the energy consumption of the building. For graphical interface the Open Studio Application Suite (https://energyplus.net/extras), a tool able to support the whole building energy modeling when using Energy Plus. has been used.

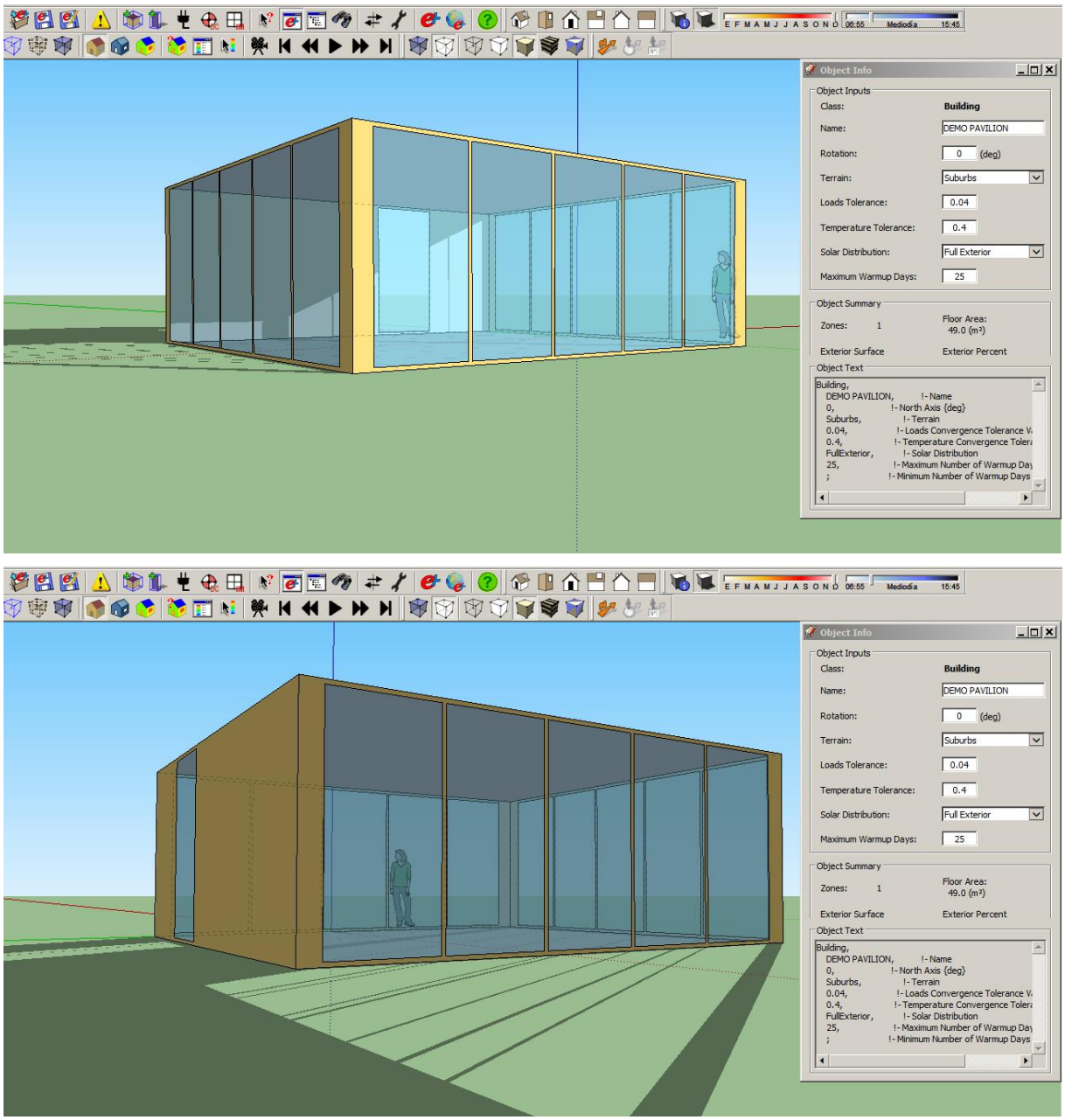


IMAGE 04, 05: SIMULATION OF 2nd PAVILION DESIGN IN SOFIA WITH ENERGYPLUS SOFTWARE 8.4.1. , IMAGES RENDERED WITH OPENSTUDIO APLIACATION SUITE PLATFORM

In simulation A, the Reference Glass has been used , and in simulation B iThermglass active glass has been used . According to previous documents, for simulations of dynamic glass, continuous water circulation is considered in the summer period and the water flow is stopped in the winter. Energy consumption from the May to September period corresponds to solar factor gON, and from the October to April period consumption corresponds to gOFF's active glass factor. Annual results are compared to those obtained through the passive Reference Glass.

SIMULATION A: PASIVE GLAZING

PASIVE GLAZING (REFERENCE GLASS)	Area [m2]	U-Factor [W/m2-K]	g VALUE	Tvis	Parent Surface	Cardinal Direction
NORTH DOOR	3.25	1.1	0.431	0.46	NORTH WALL	N
WEST WINDOW 4	3.25	1.1	0.431	0.46	WEST WALL	W
WEST WINDOW 5	3.25	1.1	0.431	0.46	WEST WALL	W
WEST WINDOW 2	3.25	1.1	0.431	0.46	WEST WALL	W
WEST WINDOW 3	3.25	1.1	0.431	0.46	WEST WALL	W
WEST WINDOW 1	3.25	1.1	0.431	0.46	WEST WALL	W
SOUTH WINDOW 5	3.25	1.1	0.431	0.46	SOUTH WALL	S
SOUTH WINDOW 3	3.25	1.1	0.431	0.46	SOUTH WALL	S
SOUTH WINDOW 2	3.25	1.1	0.431	0.46	SOUTH WALL	S
SOUTH WINDOW 1	3.25	1.1	0.431	0.46	SOUTH WALL	S
SOUTH WINDOW 4	3.25	1.1	0.431	0.46	SOUTH WALL	S
EAST WINDOW 1	3.25	1.1	0.431	0.46	EAST WALL	E
EAST WINDOW 5	3.25	1.1	0.431	0.46	EAST WALL	E
EAST WINDOW 4	3.25	1.1	0.431	0.46	EAST WALL	E
EAST WINDOW 3	3.25	1.1	0.431	0.46	EAST WALL	E
EAST WINDOW 2	3.25	1.1	0.431	0.46	EAST WALL	E

SIMULATION B: ACTIVE GLAZING

ACTIVE GLAZING (ITHERMGLASS)	Area [m2]	U-Factor [W/m2-K]	g ON	gOFF	Tvis	Parent Surface	Cardinal Direction
NORTH DOOR	3.25	1.1	0.235	0.301	0.48	NORTH WALL	N
WEST WINDOW 4	3.25	1.1	0.235	0.301	0.48	WEST WALL	W
WEST WINDOW 5	3.25	1.1	0.235	0.301	0.48	WEST WALL	W
WEST WINDOW 2	3.25	1.1	0.235	0.301	0.48	WEST WALL	W
WEST WINDOW 3	3.25	1.1	0.235	0.301	0.48	WEST WALL	W
WEST WINDOW 1	3.25	1.1	0.235	0.301	0.48	WEST WALL	W
SOUTH WINDOW 5	3.25	1.1	0.235	0.301	0.48	SOUTH WALL	S
SOUTH WINDOW 3	3.25	1.1	0.235	0.301	0.48	SOUTH WALL	S
SOUTH WINDOW 2	3.25	1.1	0.235	0.301	0.48	SOUTH WALL	S
SOUTH WINDOW 1	3.25	1.1	0.235	0.301	0.48	SOUTH WALL	S
SOUTH WINDOW 4	3.25	1.1	0.235	0.301	0.48	SOUTH WALL	S
EAST WINDOW 1	3.25	1.1	0.235	0.301	0.48	EAST WALL	E
EAST WINDOW 5	3.25	1.1	0.235	0.301	0.48	EAST WALL	E
EAST WINDOW 4	3.25	1.1	0.235	0.301	0.48	EAST WALL	E
EAST WINDOW 3	3.25	1.1	0.235	0.301	0.48	EAST WALL	E
EAST WINDOW 2	3.25	1.1	0.235	0.301	0.48	EAST WALL	E

2. Results and Discussion

A. Simulation results for Spain Demonstrator with Energy Plus

Subsequently it is presented the energy consumption, monthly and in kWh:

- Simulation A, Monthly energy consumption (Reference Glass)
- Simulation B, Monthly energy consumption (iThermglass)
  - September to May energy consumption (gON)
  - October to April energy consumption (gOFF)

Finally it is also shown a comparative table of the annual energy consumption for each case.

- Simulation A, Annual energy consumption (Reference Glass)
- Simulation B, Annual energy consumption (iThermglass)

SIMULATION A, MONTHLY ENERGY CONSUMPTION (Reference Glass)

Month	Zone Lights Electric Energy [kWh]	Zone Equipment Electric Energy [kWh]	Zone Electric Heating [kWh]	Zone Electric Cooling [kWh]	Zone Lights Electric Energy [kWh/m2]	Zone Equipment Electric Energy [kWh/m2]	Zone Electric Heating [kWh/m2]	Zone Electric Cooling [kWh/m2]
1	14,27	9,99	10,68	10,81	1,95	1,37	1,46	1,48
2	12,58	8,81	6,76	13,42	1,72	1,21	0,93	1,84
3	13,48	9,44	1,20	45,92	1,85	1,29	0,16	6,29
4	13,71	9,60	0,76	43,38	1,88	1,31	0,10	5,94
5	14,27	9,99	0,03	61,50	1,95	1,37	0,00	8,43
6	12,92	9,04	0,00	81,16	1,77	1,24	0,00	11,12
7	14,27	9,99	0,00	106,06	1,95	1,37	0,00	14,53
8	14,05	9,83	0,00	100,81	1,92	1,35	0,00	13,81
9	13,15	9,20	0,00	67,21	1,80	1,26	0,00	9,21
10	14,27	9,99	1,14	42,17	1,95	1,37	0,16	5,78
11	13,48	9,44	4,04	24,04	1,85	1,29	0,55	3,29
12	13,71	9,60	12,98	7,09	1,88	1,31	1,78	0,97
TOTAL	164,16	114,91	37,60	603,58	22,49	15,74	5,15	82,68

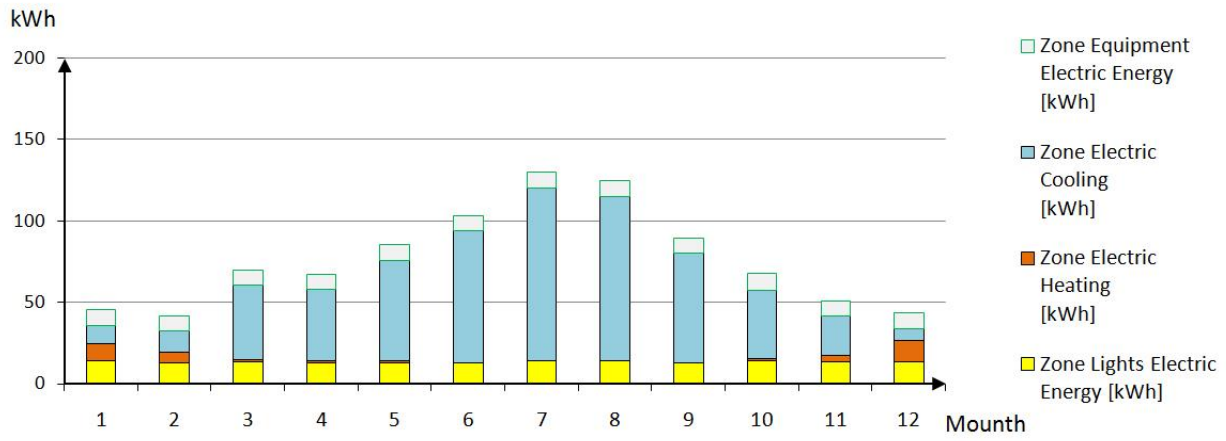


IMAGE 07: SIMULATION A, MONTLY ENERGY CONSUMTION (Reference Glass)

SIMULATION B, MONTHLY ENERGY CONSUMPTION, MAY - SEPTEMBER (iThermglass, gON)

Month	Zone Lights Electric Energy [kWh]	Zone Equipment Electric Energy [kWh]	Zone Electric Heating [kWh]	Zone Electric Cooling [kWh]	Zone Lights Electric Energy [kWh/m2]	Zone Equipment Electric Energy [kWh/m2]	Zone Electric Heating [kWh/m2]	Zone Electric Cooling [kWh/m2]
5	14,27	9,99	0,07	48,80	1,95	1,37	0,01	6,68
6	12,92	9,04	0,00	66,97	1,77	1,24	0,00	9,17
7	14,27	9,99	0,00	83,23	1,95	1,37	0,00	11,40
8	14,05	9,83	0,00	83,11	1,92	1,35	0,00	11,38
9	13,15	9,20	0,00	52,74	1,80	1,26	0,00	7,22

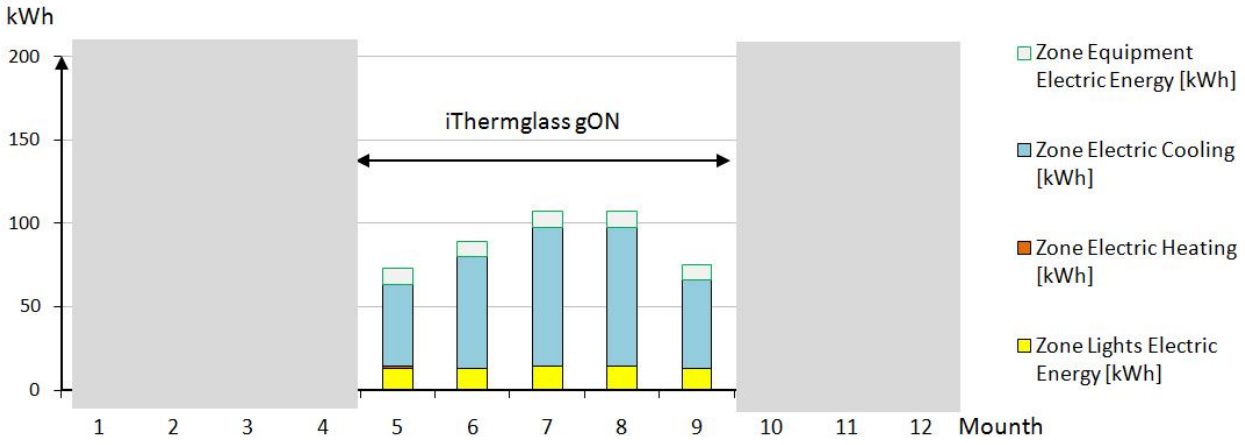


IMAGE 17: SIMULATION B, MONTLY ENERGY CONSUMTION (iThermglass, gON)

SIMULATION B, MONTHLY ENERGY CONSUMPTION, OCTOBER - APRIL (iThermglass, gOFF)

Month	Zone Lights Electric Energy [kWh]	Zone Equipment Electric Energy [kWh]	Zone Electric Heating [kWh]	Zone Electric Cooling [kWh]	Zone Lights Electric Energy [kWh/m2]	Zone Equipment Electric Energy [kWh/m2]	Zone Electric Heating [kWh/m2]	Zone Electric Cooling [kWh/m2]
1	14,27	9,99	11,11	9,76	1,95	1,37	1,52	1,34
2	12,58	8,81	7,32	12,50	1,72	1,21	1,00	1,71
3	13,48	9,44	1,34	42,09	1,85	1,29	0,18	5,77
4	13,71	9,60	0,73	43,54	1,88	1,31	0,10	5,96
11	13,48	9,44	4,40	21,78	1,85	1,29	0,60	2,98
12	13,71	9,60	13,49	6,37	1,88	1,31	1,85	0,87

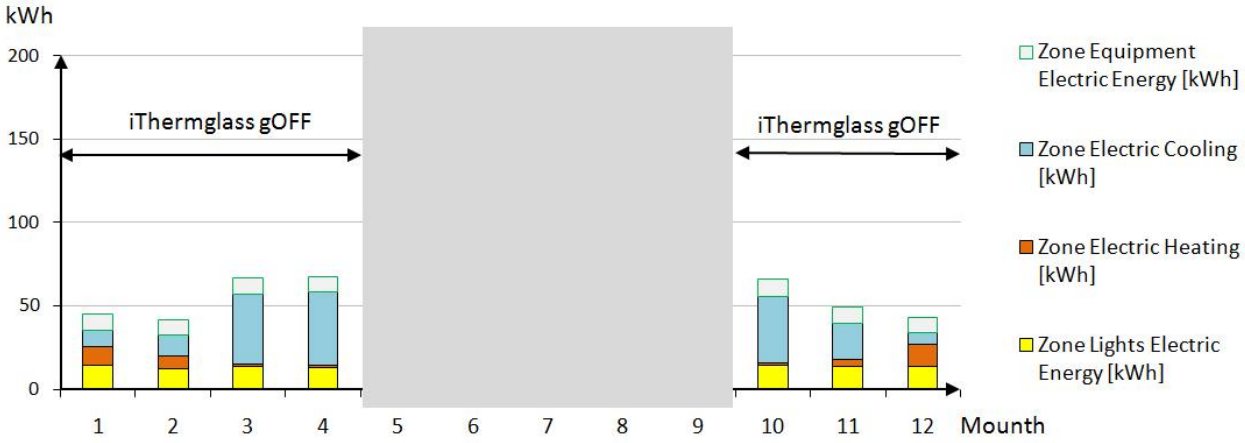


IMAGE 18: SIMULATION B, MONTLY ENERGY CONSUMTION (iThermglass, gOFF)

COMPARISON OF ANNUAL ENERGY CONSUMPTION

SIMULATION A, ANNUAL ENERGY CONSUMPTION (Reference Glass)

Delivered Energy Overview		Purchased energy	
		kWh	kWh/m2
	Lighting, facility	164,16	22,49
	Electric cooling	603,58	82,68
	Electric heating	37,60	5,15
	Domestic hot water	0,00	0,00
	Equipment, tenant	114,91	15,74
	Grand total	**920,24**	**126,06**

SIMULATION B, ANNUAL ENERGY CONSUMPTION (iThermglass)

Delivered Energy Overview		Purchased energy	
		kWh	kWh/m2
	Lighting, facility	164,16	22,49
	Electric cooling	470,87	64,50
	Electric heating	38,48	5,27
	Domestic hot water	0,00	0,00
	Equipment, tenant	114,91	15,74
	Grand total	**788,41**	**108,00**

CONCLUSION

In Madrid, savings in cooling obtained through replacing the passive glazing Reference Glass by the active glazing iThermglass are about 21.98%.

This saving is slightly lower than that of the Bulgarian demonstrator, in which it was around 25%. In the case of Madrid, the small size of the demonstrator does not allow higher savings to be achieved and to take advantage of the active glass on cooling more widely.

As well as in the case of the Bulgarian demonstrator, no savings are obtained in heating through replacing the passive glazing Reference glass by iThermglass. Although the thermal transmittance (U) is maintained, solar gains are reduced, so heating consumption is increased.

B. Simulation results for Sofia Demonstrator with Energy Plus

Subsequently the electric type energy consumption is represented, due to the lighting, the heat pump in the heating and cooling system, and the operation of equipment, all of them monthly, in kWh. The consumption of domestic hot water has been considered zero.

Simulation A, Monthly energy consumption (Reference Glass)
Simulation B, Monthly energy consumption (iThermglass)
September to May energy consumption (gON)
October to April energy consumption (gOFF)

Finally we present a comparative of the annual energy consumption for each case.

Simulation A, Annual energy consumption (Reference Glass)
Simulation B, Annual energy consumption (iThermglass)

SIMULATION A, MONTHLY ENERGY CONSUMPTION (Reference Glass)

Month	Zone Lights Electric Energy [kWh]	Zone Equipment Electric Energy [kWh]	Zone Electric Heating [kWh]	Zone Electric Cooling [kWh]	Zone Lights Electric Energy [kWh/m2]	Zone Equipment Electric Energy [kWh/m2]	Zone Electric Heating [kWh/m2]	Zone Electric Cooling [kWh/m2]
1	95,65	66,95	102,41	8,02	1,95	1,37	2,09	0,16
2	87,81	61,47	65,40	11,38	1,79	1,25	1,33	0,23
3	99,57	69,70	35,91	31,30	2,03	1,42	0,73	0,64
4	90,16	63,11	6,68	73,00	1,84	1,29	0,14	1,49
5	99,57	69,70	0,00	88,50	2,03	1,42	0,00	1,81
6	95,65	66,95	0,00	147,67	1,95	1,37	0,00	3,01
7	94,08	65,86	0,00	177,35	1,92	1,34	0,00	3,62
8	99,57	69,70	0,00	162,64	2,03	1,42	0,00	3,32
9	94,08	65,86	0,00	109,91	1,92	1,34	0,00	2,24
10	95,65	66,95	17,41	57,99	1,95	1,37	0,36	1,18
11	95,65	66,95	68,76	13,46	1,95	1,37	1,40	0,27
12	94,08	65,86	98,20	5,18	1,92	1,34	2,00	0,11
TOTAL	1141,50	799,05	394,76	886,38	23,30	16,31	8,06	18,09

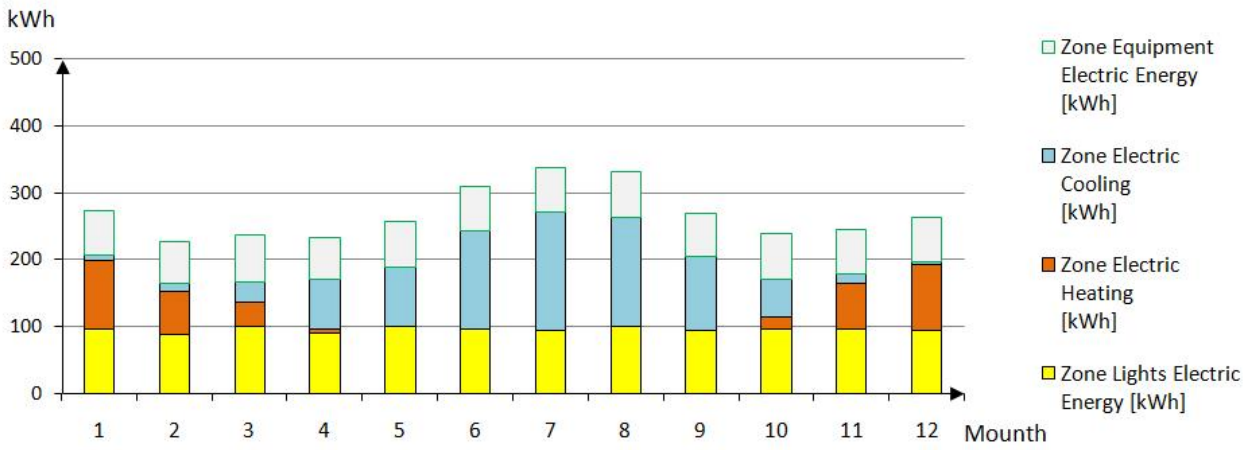


IMAGE16: SIMULATION A, MONTLY ENERGY CONSUMTION (Reference Glass)

SIMULATION B, MONTHLY ENERGY CONSUMPTION, MAY - SEPTEMBER (iThermglass, gON)

Month	Zone Lights Electric Energy [kWh]	Zone Equipment Electric Energy [kWh]	Zone Electric Heating [kWh]	Zone Electric Cooling [kWh]	Zone Lights Electric Energy [kWh/m2]	Zone Equipment Electric Energy [kWh/m2]	Zone Electric Heating [kWh/m2]	Zone Electric Cooling [kWh/m2]
5	99,57	69,70	3,13	62,82	2,03	1,42	0,06	1,28
6	95,65	66,95	0,00	106,11	1,95	1,37	0,00	2,17
7	94,08	65,86	0,00	131,33	1,92	1,34	0,00	2,68
8	99,57	69,70	0,00	120,63	2,03	1,42	0,00	2,46
9	94,08	65,86	0,00	78,78	1,92	1,34	0,00	1,61

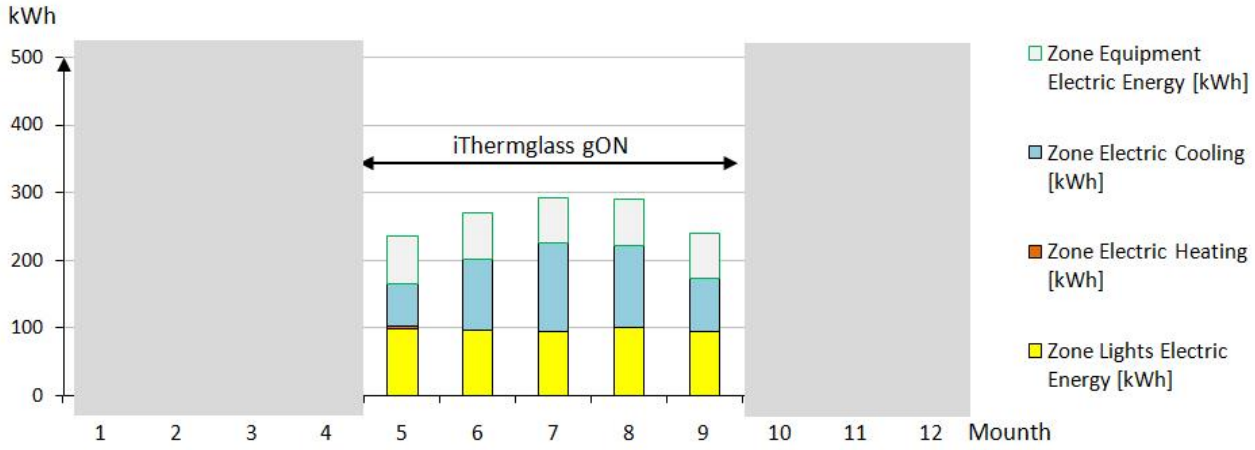


IMAGE 17: SIMULATION B, MONTLY ENERGY CONSUMTION (iThermglass, gON)

SIMULATION B, MONTHLY ENERGY CONSUMPTION, OCTOBER - APRIL (iThermglass, gOFF)

Month	Zone Lights Electric Energy [kWh]	Zone Equipment Electric Energy [kWh]	Zone Electric Heating [kWh]	Zone Electric Cooling [kWh]	Zone Lights Electric Energy [kWh/m2]	Zone Equipment Electric Energy [kWh/m2]	Zone Electric Heating [kWh/m2]	Zone Electric Cooling [kWh/m2]
1	95,65	66,95	106,97	6,72	1,95	1,37	2,18	0,14
2	87,81	61,47	72,05	9,35	1,79	1,25	1,47	0,19
3	99,57	69,70	42,30	25,98	2,03	1,42	0,86	0,53
4	90,16	63,11	8,21	63,26	1,84	1,29	0,17	1,29
11	95,65	66,95	73,35	11,43	1,95	1,37	1,50	0,23
12	94,08	65,86	102,23	4,43	1,92	1,34	2,09	0,09

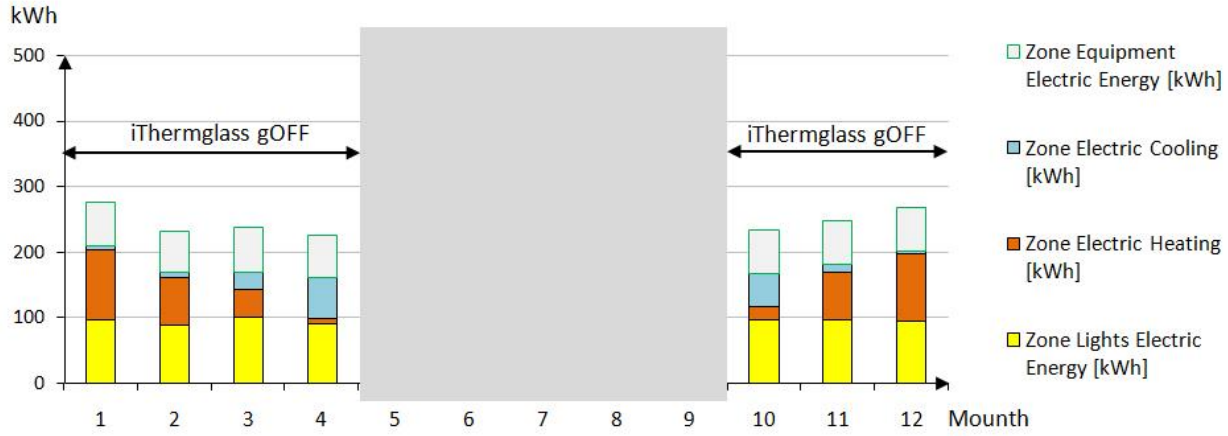


IMAGE 18: SIMULATION B, MONTLY ENERGY CONSUMTION (iThermglass, gOFF)

COMPARISON OF ANNUAL ENERGY CONSUMPTION

SIMULATION A, ANNUAL ENERGY CONSUMPTION (Reference Glass)

Delivered Energy Overview		Purchased energy	
		kWh	kWh/m2
	Lighting, facility	1141,50	23,30
	Electric cooling	886,38	18,09
	Electric heating	394,76	8,06
	Domestic hot water	0,00	0,00
	Equipment, tenant	799,05	16,31
	Grand total	**3221,70**	**65,75**

SIMULATION B, ANNUAL ENERGY CONSUMPTION (iThermglass)

Delivered Energy Overview		Purchased energy	
		kWh	**kWh/m2**
	Lighting, facility	1045,86	21,34
	Electric cooling	620,84	12,67
	Electric heating	408,23	8,33
	Domestic hot water	0,00	0,00
	Equipment, tenant	732,10	14,94
	Grand total	**2807,02**	**57,29**

CONCLUSION

In the second design of the demonstrator in Bulgaria, lighting energy consumption is the same as that of in the first design. Similarly, the power consumption in equipment per square meter of local interior surface is within the same order.

The heat pump power consumption in heating, in overall terms, is lower than in previous design, due to the reduction of the size of this second building. However, considering consumption in heating per square meter, it is slightly higher in the second design because the envelope per indoor air volume ratio is higher, and heat losses increase slightly. The heat pump power consumption in cooling per surface unit is within the same order as the preliminary design.

Focusing on this second design, annual savings in cooling obtained by replacing Reference Glass by iThermglass are around 25.1%.

By changing Reference Glass by iThermglass no heating savings are obtained. Although the thermal transmittance (U value) is maintained, the g factor of the iThermglass gives rise to a rediction in solar gains, so no better results in heat consumption are achieved.

3. Degree of Progress

No delay or modification in the work plan is reported.

4. Dissemination

Neither this work nor any part of it has been published before.

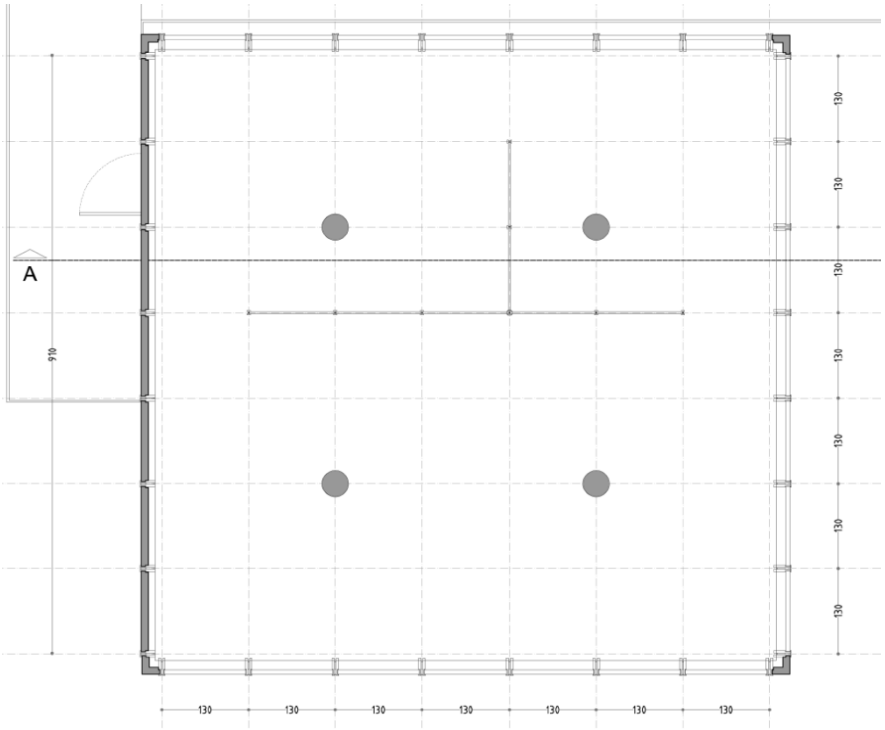
Appendix: Simulation of Sofia Demonstrator with IDA ICE

BASELINE

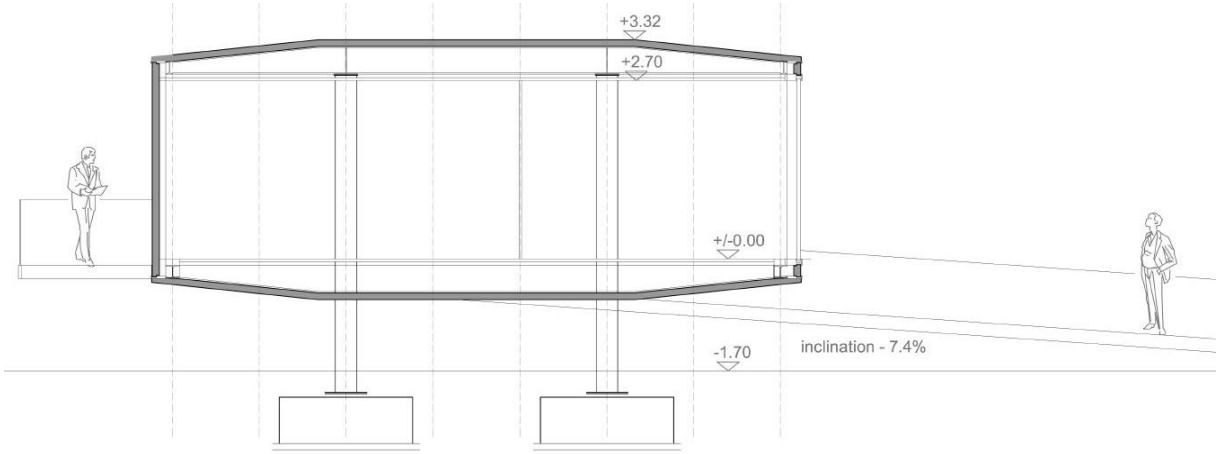
In this report energy, the simulation of a small-sized building (demonstrator) located in Sofia is selected. It is scheduled to be built in the Sofia Tech Park.

The main goals of this study are to evaluate how the different technologies that are implemented in it are performing and to show the innovative technologies related to the construction of zero energy buildings, as set out in the 2010/31/UE directive, and making use of renewable solar energy. In addition to acting as demonstrator, it will be meeting place and venue for events.

The building is a stand-alone construction witha square geometry, and is deployed in a single plan of outer dimensions 10 x 10 m, and a ceiling height of 2.7 m, with open office design and a central service core. Three of the facades are fully glazed, from floor to ceiling, except the north façade which is 100% opaque. The glass facades are composed of modules of glass with dimensions of 2.7 x 1.3 m.



IMAGES 01, 02: PLANT AND SECTION OF BUILDING DEMONSTRATOR IN SOFIA



SIMULATION MODEL

ENVELOPE MATERIALS

The table defines the constructive composition of the floor of the building in contact with the external environment, as well as its thickness (cm), surface (m²) and the thermal transmittance U-value (W/m²K) of the set of layers that make up the floor.

FLOOR	THICKNESS [cm]	U-FACTOR [W/m²-K]	AREA [m²]
Flooring: PVC 0.4 cm +Chipboard 2 cm + Concrete slab 30 cm +Air Chamber 1 m	32.4 + 100	1.468	100.0

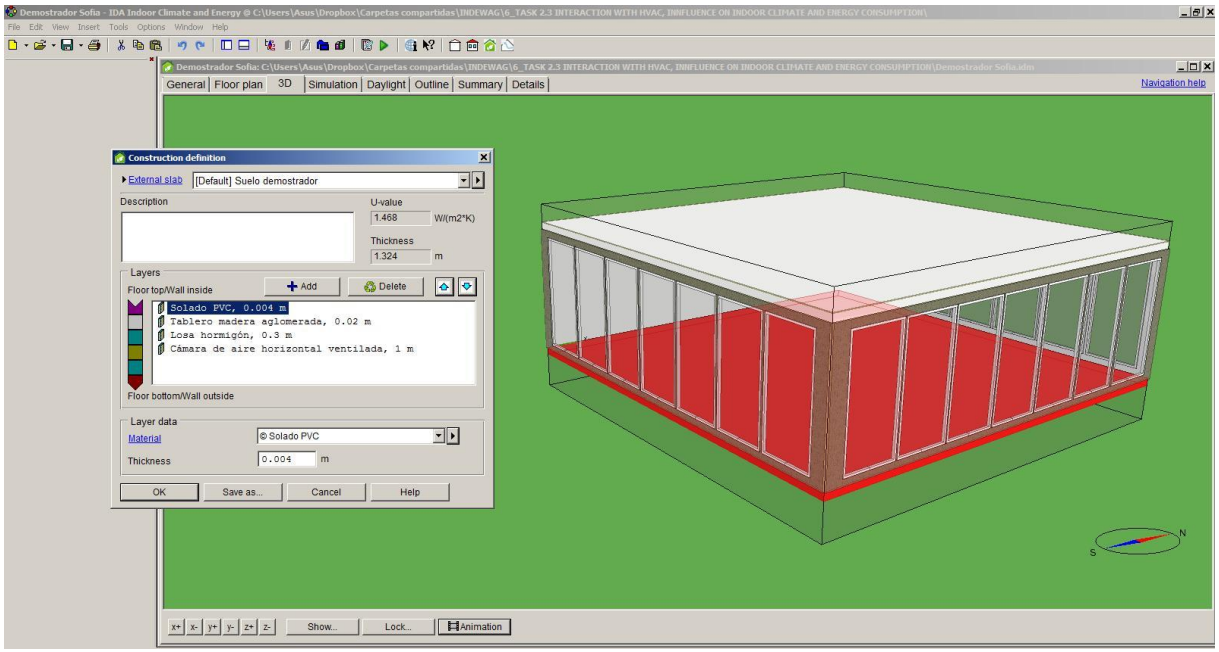


IMAGE 03: CONSTRUCTIVE DEFINITION OF THE FLOOR OF DEMONSTRATOR

The other building components can be listed as following:

ROOF	THICKNESS [cm]	U-FACTOR [W/m²-K]	AREA [m²]
Sheet metal mini wave 0.04 cm + 15 cm air chamber + extruded polystyrene 6 cm + concrete slab 30 cm + 2 cm particleboard + sheet metal 0.04 cm finishing.	53.8	0.396	100.0

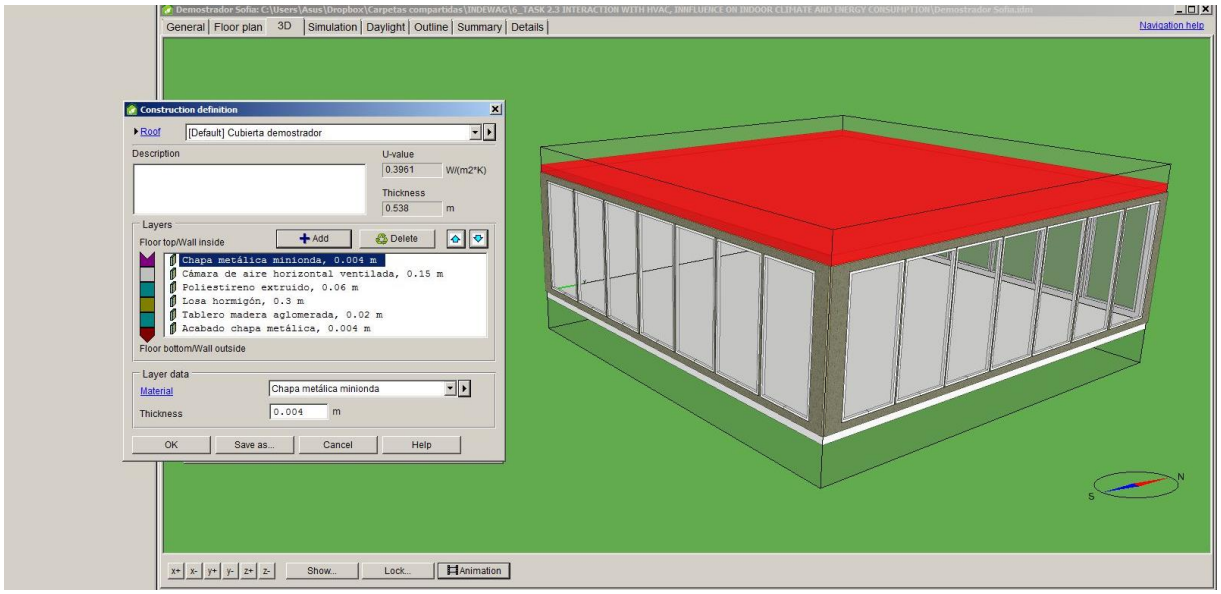


IMAGE 04: CONSTRUCTIVE DEFINITION OF DEMONSTRATOR ROOF

FAÇADES	THICKNESS [cm]	U-FACTOR [W/m²-K]	AREA [m²]
Sandwich Panel (Sheet metal 0.04 cm + Polyurethane 0.0392 cm)	4.0	0.677	30.0

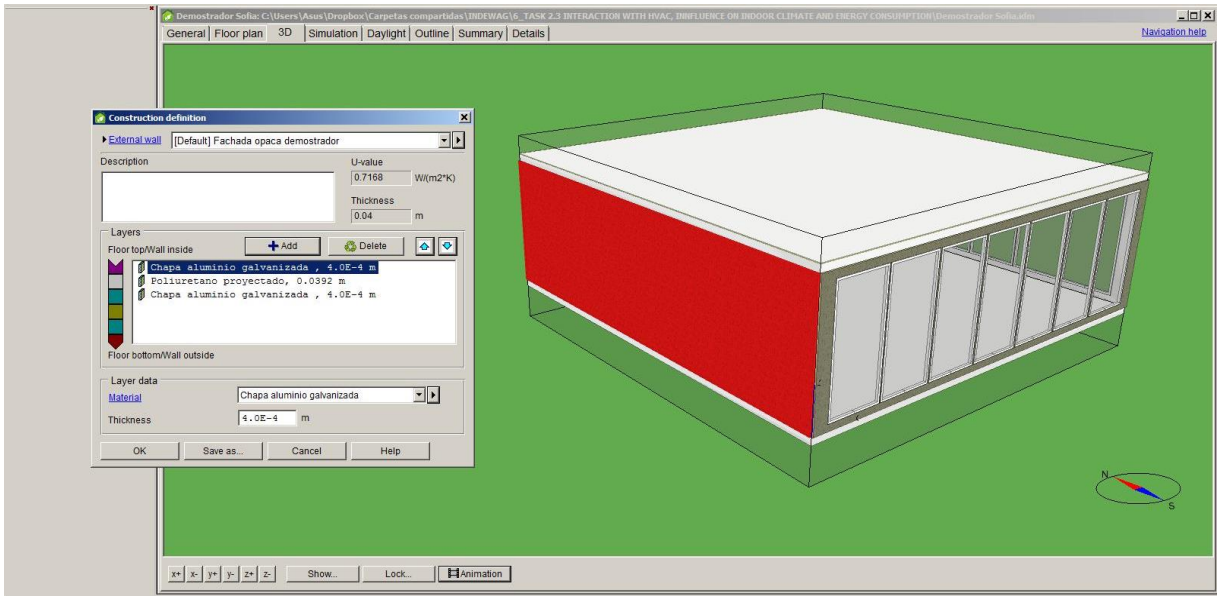


IMAGE 05: CONSTRUCTIVE DEFINITION OF FACADE OF DEMONSTRATOR

Energy consumption due to the use of passive glazing on the façade of the demonstrator, called Reference Glass, is compared with the consumption obtained when installing the active facade iThermglass. The passive glazing **Reference Glass** consists of a double glazing with exterior solar control and argon chamber (6 mm/16 mm (argon)/ 6 mm), with Cool-lite film ST150 on the inner face of the outer glass (source: Reference Glazing Catalogue).

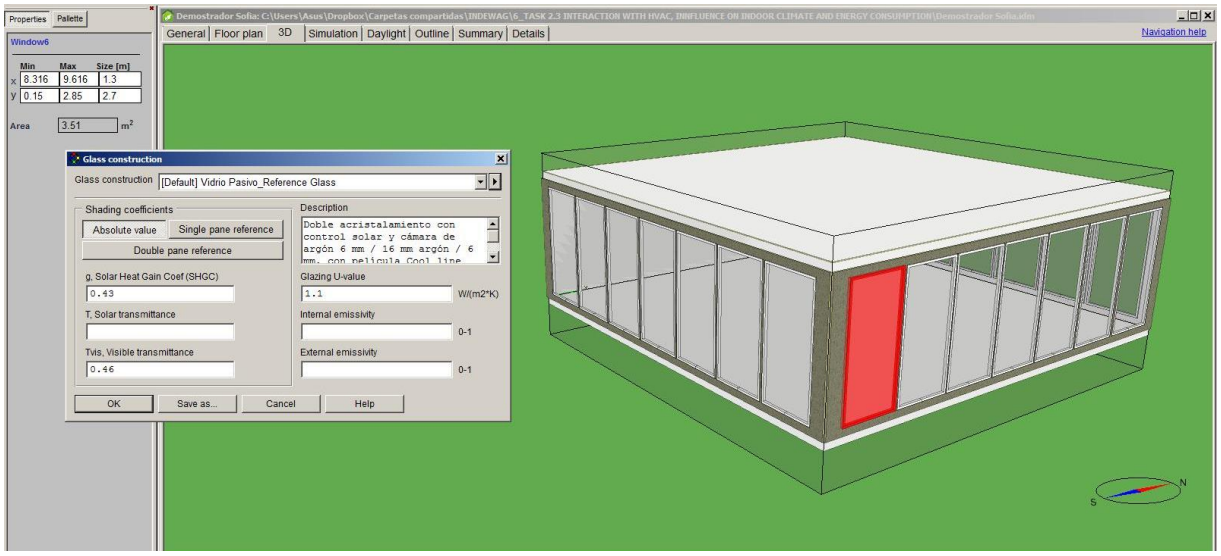


IMAGE 06: TYPE REFERENCE GLASS GLAZING

Active glass system, **iThermglass,** consists of a triple glazing with solar control, water chamber and argon (10 + 4 mm/16 mm water chamber/ 4 + 10 mm / 16 mm argon / 4 + 4 mm), with Saflex R solar (SG41) film on the exterior glass, Saflex R standard (RB11) in the middle and interior glasses (source: Reference Glazing Catalogue).

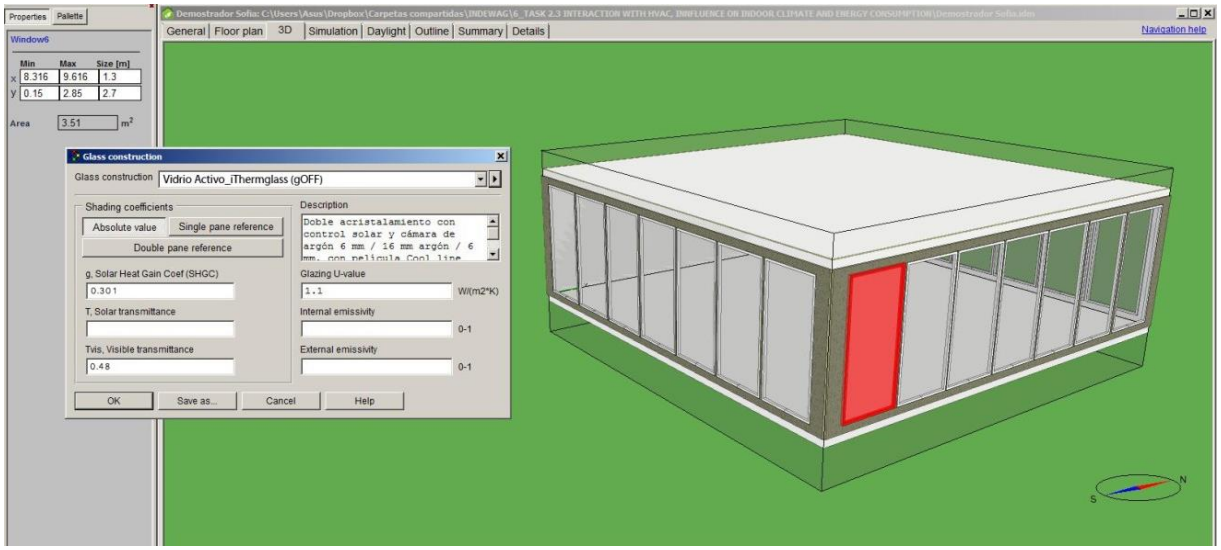


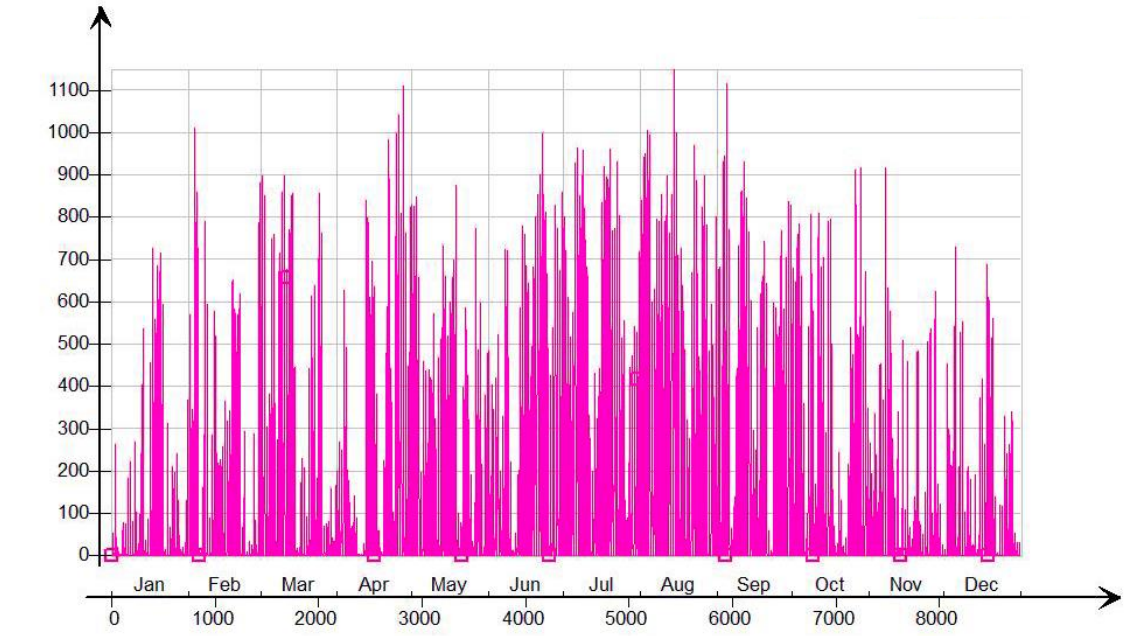
IMAGE 07: GLAZING TYPE ITHERMGLASS USO DEL EDIFICIO

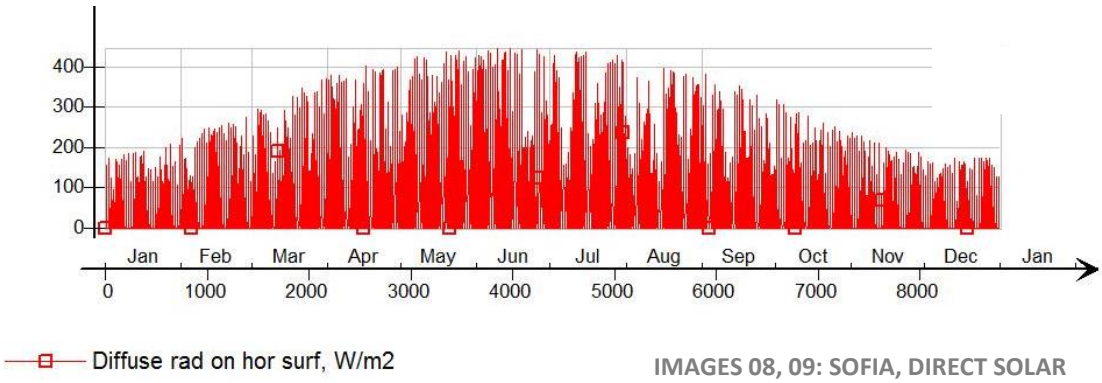
For the annual simulation of the building in IDA-ICE, the occupation of the office considered as Monday to Friday 8:00 to 18:00, and 8:00 to 14:00 on Saturdays.

CLIMATIC CONDITIONS

For energy simulations the climatic file developed by ASHRAE is used (American Society of Heating Refrigerating and Air-Conditioning Engineers), made from average annual data supplied by weather stations and available on the EnergyPlus official website (https://energyplus.net/weather).

The characteristic curves of the city of Sofia are set out below, in terms of the amount of annual direct and diffuse solar radiation and its temperature. Equally, weather conditions typical of the summer solstice week in Sofia, by the curves of the dry bulb temperature, percentage of relative humidity of air, normal direct radiation on a horizontal surface, normal radiation diffuse on horizontal surface, wind, and percentage of cloud cover in the sky are also presented. Weekly curves are easier to understand and watch, as annual ones have so much information compressed.





IMAGES 08, 09: SOFIA, DIRECT SOLAR RADIATION AND DIFFUSE ANNUAL (W)

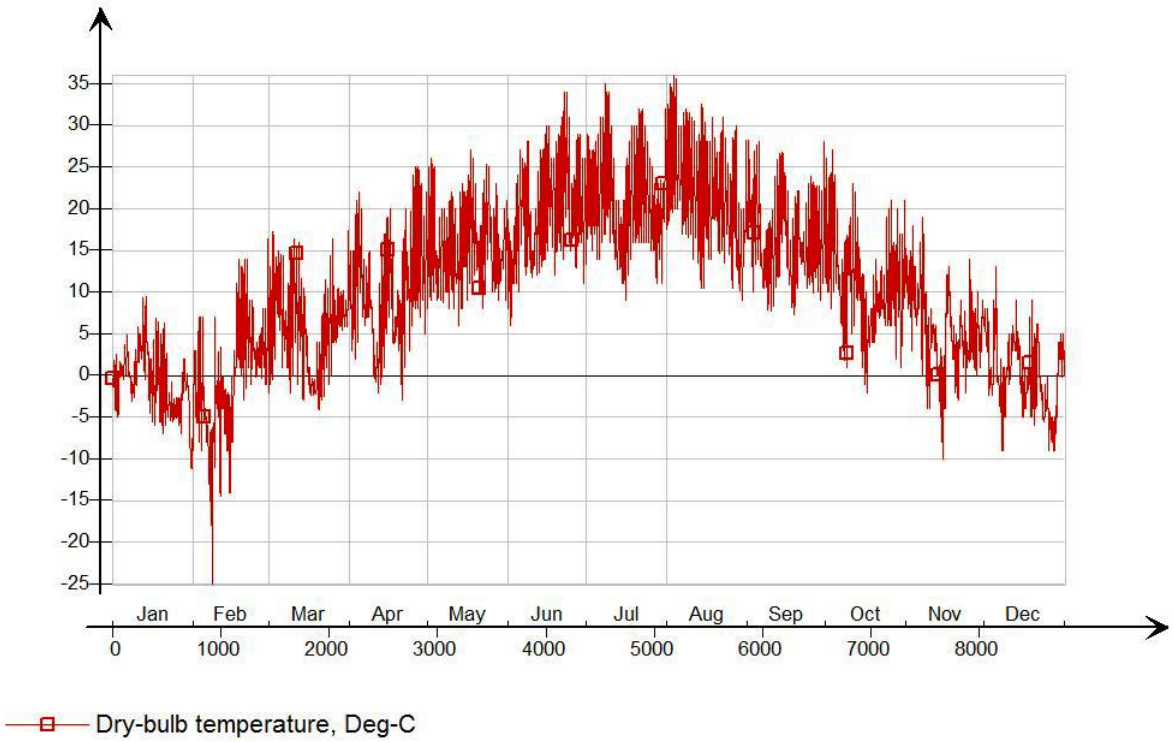


IMAGE 10: SOFIA, ANNUAL TEMPERATURE (° C)

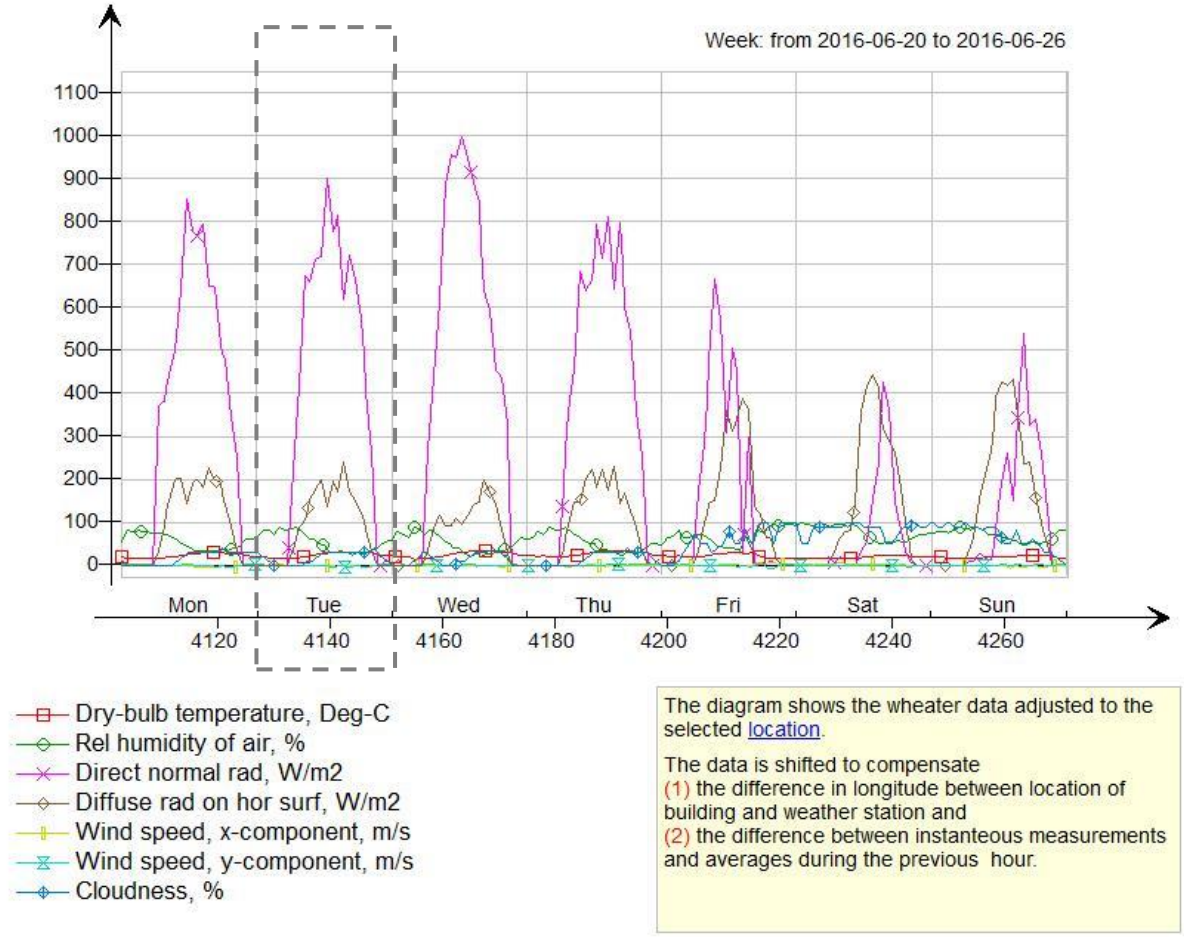


IMAGE 11: SOFIA, CLIMATIC CONDITIONS, CHARACTERISTICS OF THE SUMMER SOLSTICE

INTERNAL LOADS

During the building use, the following internal gains are estimated:

- Equipment loads: 7 W/m²
- Lighting loads: 10 W/m²
- Occupation loads, considering an occupation of 0,1 people per square meter: 5 W/m²

CONDITIONING SYSTEM

To obtain electricity consumption in air conditioning, it has been determined that the building has a heat pump system, both for heating and cooling. The selected heat pump has a COP (Coefficient of Performance) applied to heating of 3.21 and an EER (Energy Efficiency Ratio) equivalent to 3.61 in refrigeration.

TEMPERATURE SETTINGS

The set temperatures for heating and cooling are 21°C and 25°C respectively

RESULTS OF GROUP 1 OF SIMULATIONS

The results of Group 1 of simulations are presented in the following order: first weekly heat balance curves, with active and passive glass (Reference Glass 1A) (1B, iThermglass) are compared. Most representative weeks of the year are chosen, corresponding to the winter and summer solstice.

Simulation 1A, Summer solstice (Reference Glass)

Simulation 1B, Summer solstice (iThermglass gON)

Simulation 1A, Winter solstice (Reference Glass)

Simulation 1B, Winter solstice (iThermglass gOFF)

Curves of weekly heat balance, are broken down as follows: amount of heat due to the temporary occupation of the building; amount of heat provided by the equipment in operation; heat due to the lighting during the opening hours of the building; heat transmitted between outside and inside through the opaque envelope (roof, floor and facades); solar gain through the glazing (considering the amount of direct and diffuse radiation which penetrates to the interior); contribution or extraction of heat by air conditioning (heating or cooling); heat transmitted by holes or openings; transmission through thermal bridges; and net losses of heat.

Subsequently the electric type energy consumption, due to the lighting, and the heat pump in heating and cooling system, and consumption due to the operation of equipment, all of them monthly, in kWh is represented. The consumption of domestic hot water has been considered zero.

Simulation 1A, Monthly energy consumption (Reference Glass)

Simulation 1B, Monthly energy consumption (iThermglass)

September to May energy consumption (gON)

Octobers to April energy consumption (gOFF)

Finally we present a comparative of the annual energy consumption for each case.

Simulation 1A, Annual energy consumption (Reference Glass)

Simulation 1B, Annual energy consumption (iThermglass)

RESULTS OF GROUP 2 OF SIMULATIONS

Also the results of group 2 of simulations are presented in the same order:

Simulation 2A, Summer solstice (Reference Glass)

Simulation 2B, Summer solstice (iThermglass gON)

Simulation 2A, Winter solstice (Reference Glass)

Simulation 2B, Winter solstice (iThermglass gOFF)

Simulation 2A, Monthly energy consumption (Reference Glass)

Simulation 2B, Monthly energy consumption (iThermglass)

September to May energy consumption (gON)

Octobers to April energy consumption (gOFF)

Simulation 2A, Annual energy consumption (Reference Glass)

Simulation 2B, Annual energy consumption (iThermglass)

DISCUSSIONS

Comparison of results is always made to evaluate different behavior of iThermglass (B simulations) and Reference Glass (A simulations).

Group 1

Group 1 simulations refer to a simulation model with a 100% glazed façade. In annual simulations a remarkable reduction in electric cooling of about 42%can be observed due to the use of iThermglass. However in electric heating there is a rise of about 12%. As electric

cooling figures are much higher than those of heating, the final result is an improvement of almost 30% reduction in both electric heating and cooling (p. 20).

To have a better picture of the façade performance, a monthly comparison has also been carried out. While in the October to April period, with the iThermglass switched off, there is no relevant difference in energy demands, whilst in the May to September period the reduction in the main energy demands takes place, with a reduction of about a 25% in peak energy demand (image 16-17).

Finally in selected week curves, like that representative of summer and winter solstice, taking an average day, highlighted by a box line, it can be seen that while in winter the differences are small, with slightly higher solar gain in Reference Glass simulation, leading to some cooling demands even in winter (image 14), in summer bigger differences can be observed, with peak energy demands of almost 32% higher in Reference Glass simulation, versus iTermglass (g- on) simulation (image 12-13).

Group 2

Group 2 simulations refer to a simulation model with a 50% glazed façade. In annual simulations, a remarkable reduction in electric cooling of about 34%, can also be observed due to the use of iThermglass. Now figures are lower (54%) due to a better performance of the opaque façade. However in electric heating there is a rise of about 13%. As electric cooling figures continue to be much higher than those of the heating, the final result is an improvement of almost a 19% reduction in both electric heating and cooling (p. 29).

Again to better understand the façade performance, monthly comparison has been also carried out. While in the October to April period, with iThermglass switched off, there is no relevant difference in energy demands, in the May to September period there is a reduction in the main energy demands, with a peak energy demand reduction of about a 26% (image 23-24).

Finally in selected week curves, like that representative of the summer and winter solstice, taking an average day, it can be seen that while in winter the differences are small, with a slightly higher solar gain in Reference Glass simulation (image 21-22), in summer bigger differences can be observed again, with peak energy demands of almost 32% higher in Reference Glass simulation, versus the iTermglass (g- on) simulation (image 12-13).

Both in Group 1 and 2 simulations, the same pattern is observed: electric cooling demands are reduced noticeably, while heating demands hardly rise. This effect is higher in the 100% glazed façade model, what means that FFG will be more effective in this type of building.

SIMULATION 1A, SUMMER SOLSTICE (Reference Glass)

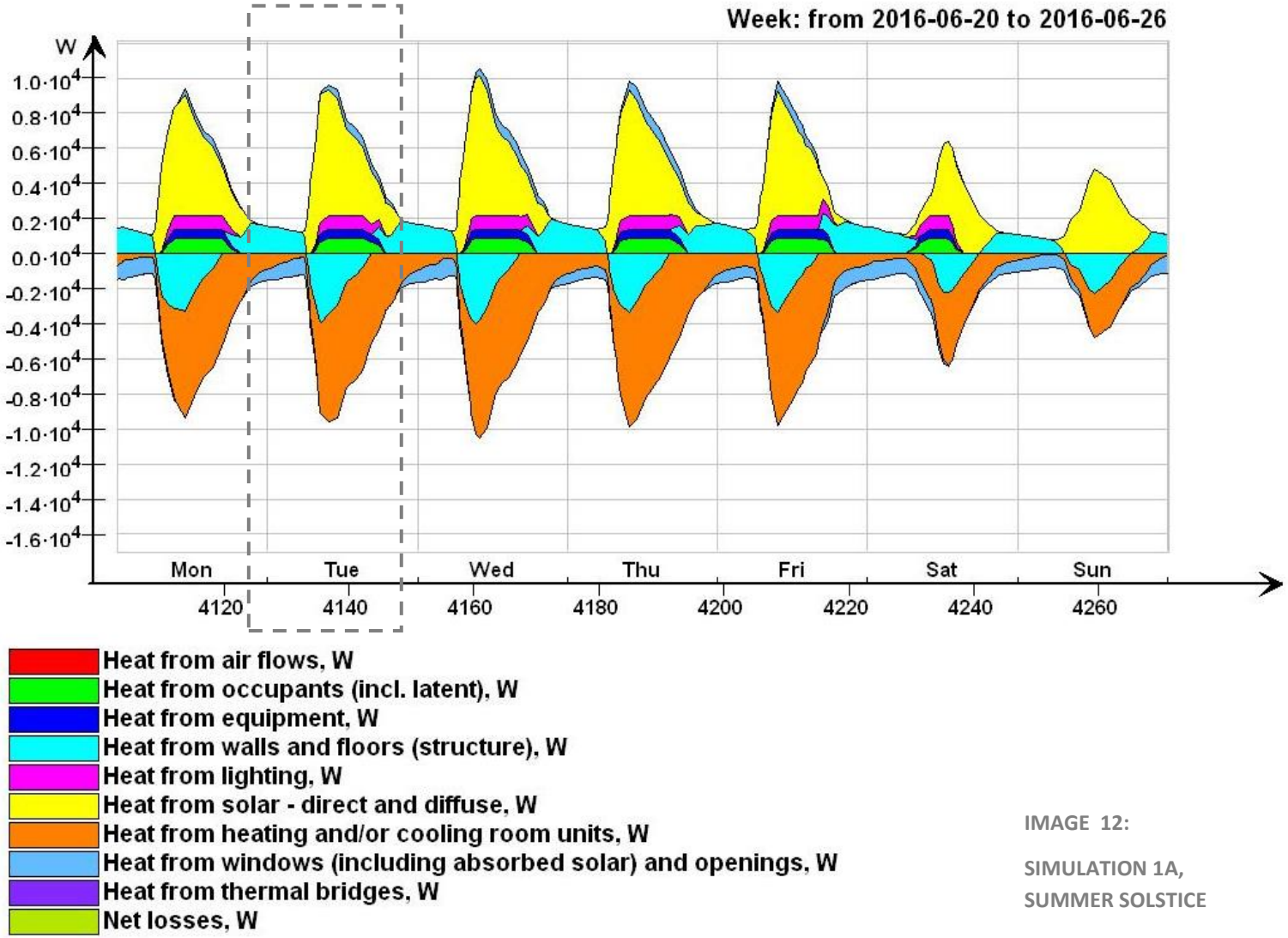


IMAGE 12:

SIMULATION 1A, SUMMER SOLSTICE

SIMULATION 1B, SUMMER SOLSTICE (iThermglass gON)

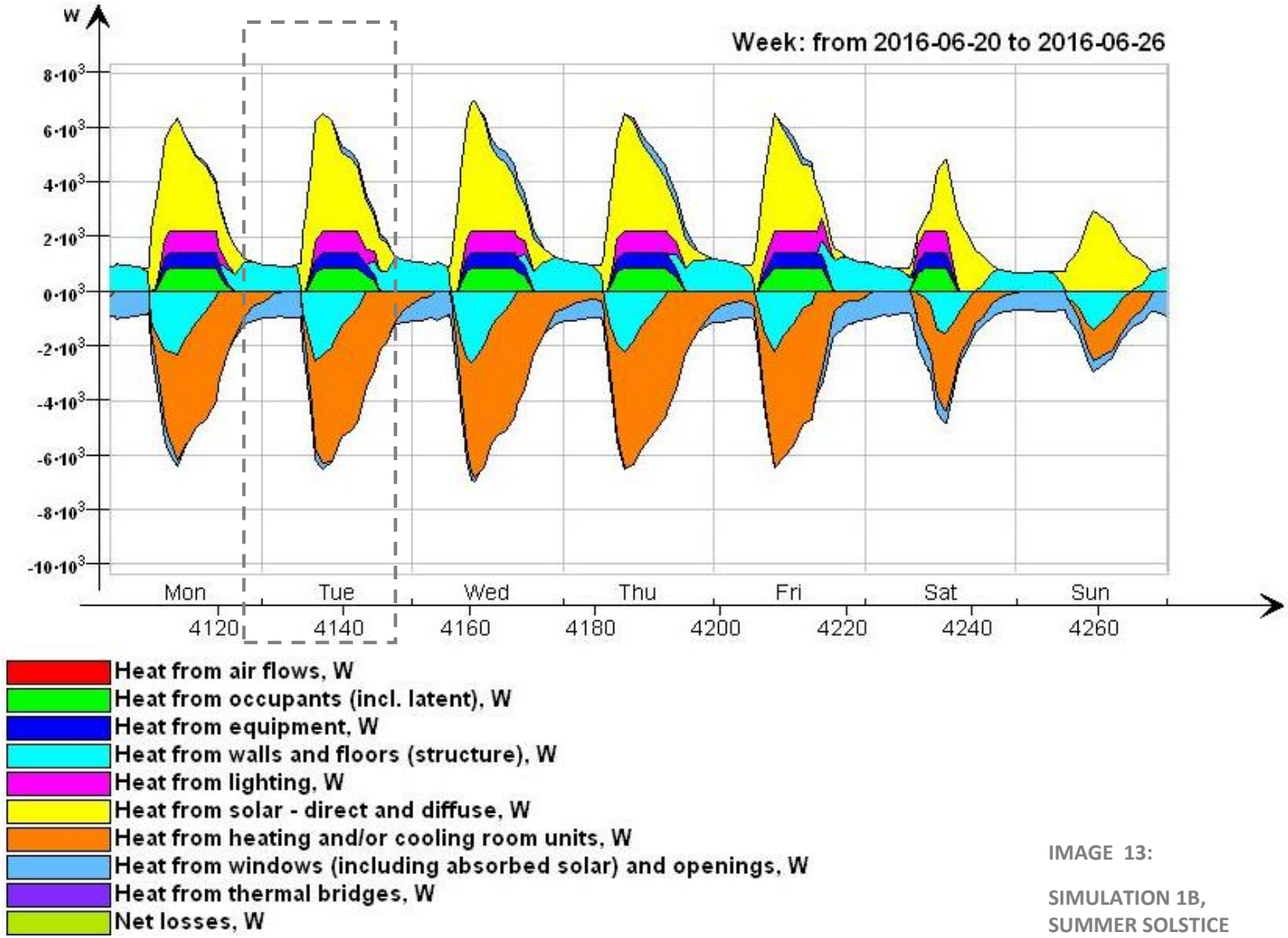


IMAGE 13:

SIMULATION 1B, SUMMER SOLSTICE

SIMULATION 1A, WINTER SOLSTICE (Reference Glass)

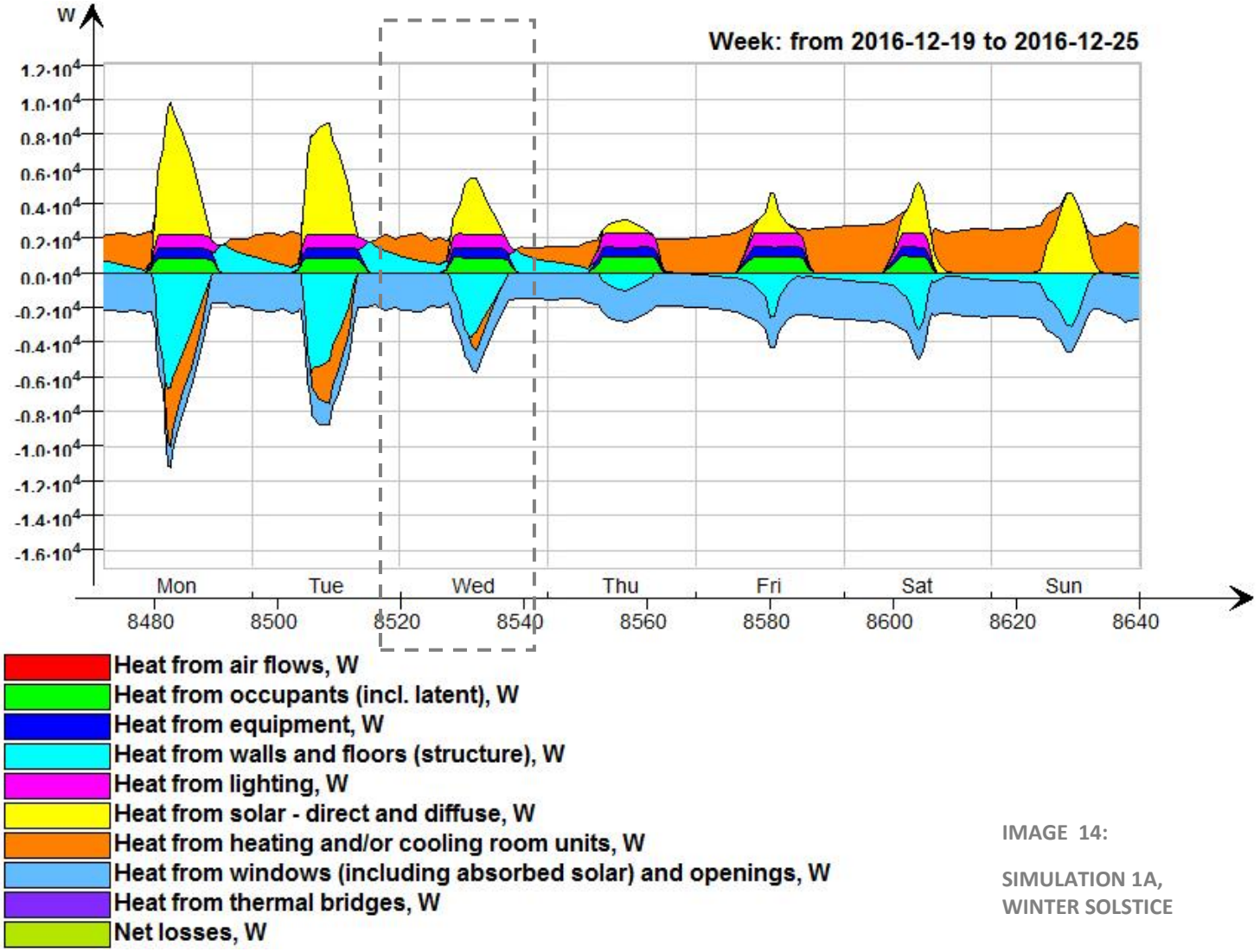


IMAGE 14:

SIMULATION 1A,
WINTER SOLSTICE

SIMULATION 1B, WINTER SOLSTICE (iThermglass gOFF)

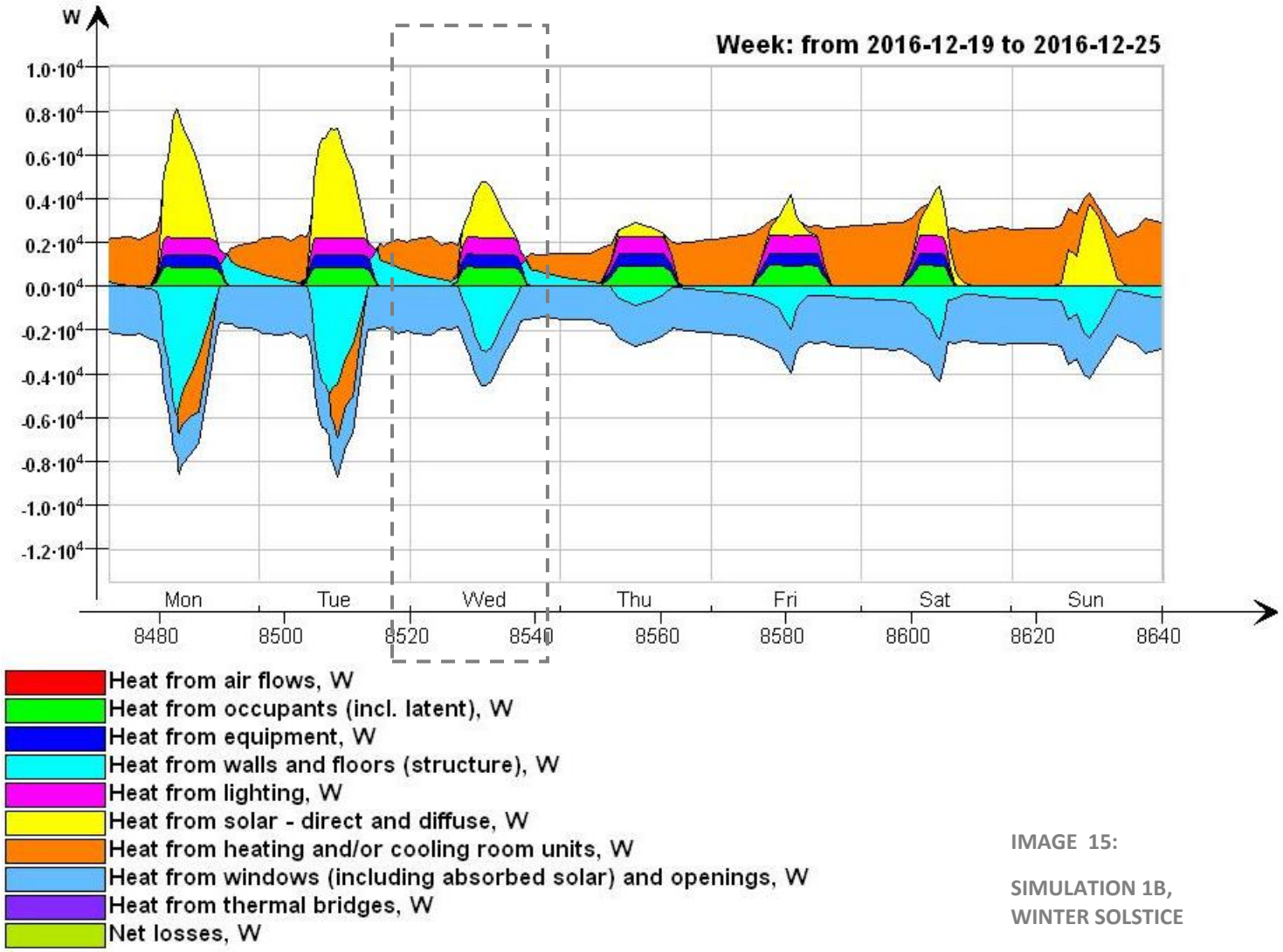
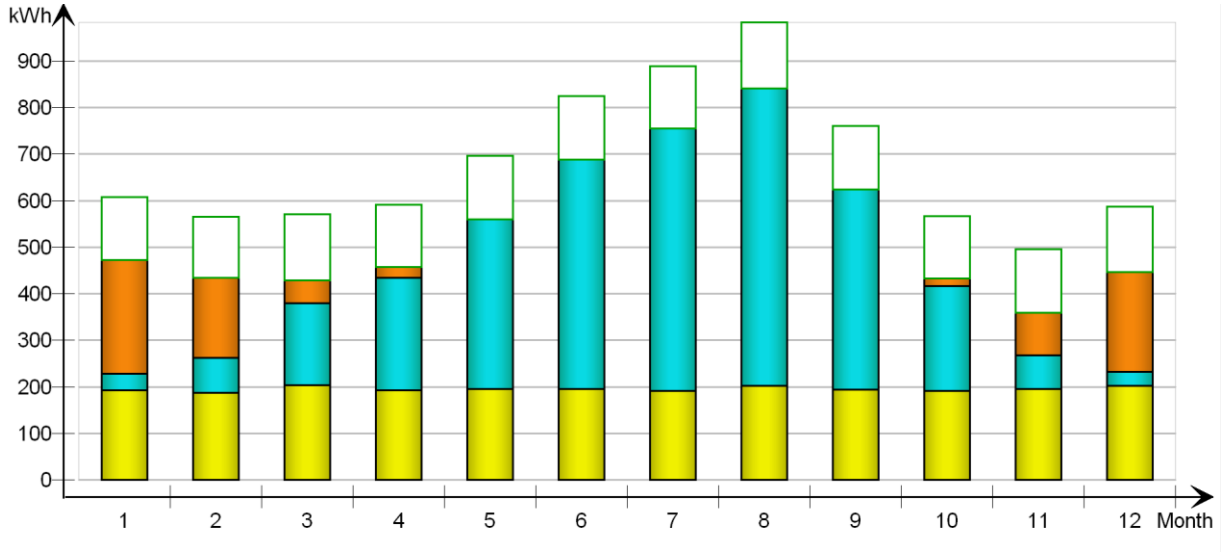


IMAGE 15:

SIMULATION 1B, WINTER SOLSTICE

SIMULATION 1A, MONTHLY ENERGY CONSUMPTION (Reference Glass)

Month	Facility electric			Facility fuel	Tenant electric
	Lighting, facility	Electric cooling	Electric heating	Domestic hot water	Equipment, tenant
	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)
1	192.6	35.1	244.5	0.0	134.8
2	187.6	74.9	172.1	0.0	131.3
3	202.8	176.4	49.7	0.0	142.0
4	191.9	241.5	23.3	0.0	134.3
5	194.9	364.4	0.0	0.0	136.4
6	194.6	493.3	0.0	0.0	136.2
7	191.4	564.1	0.0	0.0	134.0
8	202.7	638.5	0.0	0.0	141.9
9	194.4	430.3	0.0	0.0	136.1
10	191.7	225.4	16.6	0.0	134.2
11	195.6	72.9	91.9	0.0	136.9
12	201.5	30.6	214.9	0.0	141.0
Total	2341.7	3347.3	813.0	0.0	1639.1



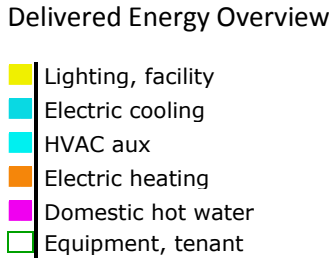
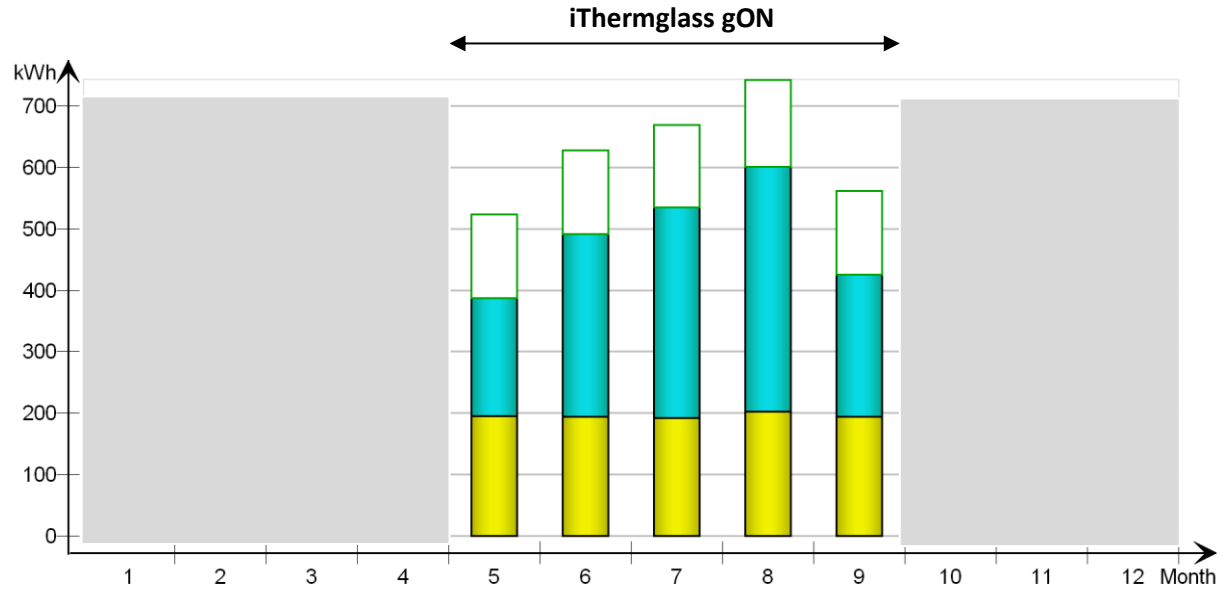


IMAGE 16:

SIMULATION 1A, MONTLY ENERGY CONSUMTION

SIMULATION 1B, MONTHLY ENERGY CONSUMPTION, MAY - SEPTEMBER (iThermglass gON)

Month	Facility electric			Facility fuel	Tenant electric
	Lighting, facility	Electric cooling	Electric heating	Domestic hot water	Equipment, tenant
	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)
5	195.0	192.5	0.0	0.0	136.5
6	194.5	297.4	0.0	0.0	136.1
7	191.7	343.3	0.0	0.0	134.2
8	202.8	398.8	0.0	0.0	141.9
9	194.6	231.6	0.0	0.0	136.2



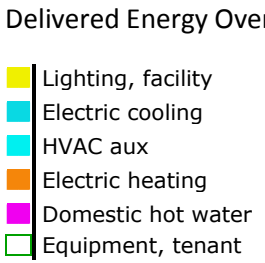
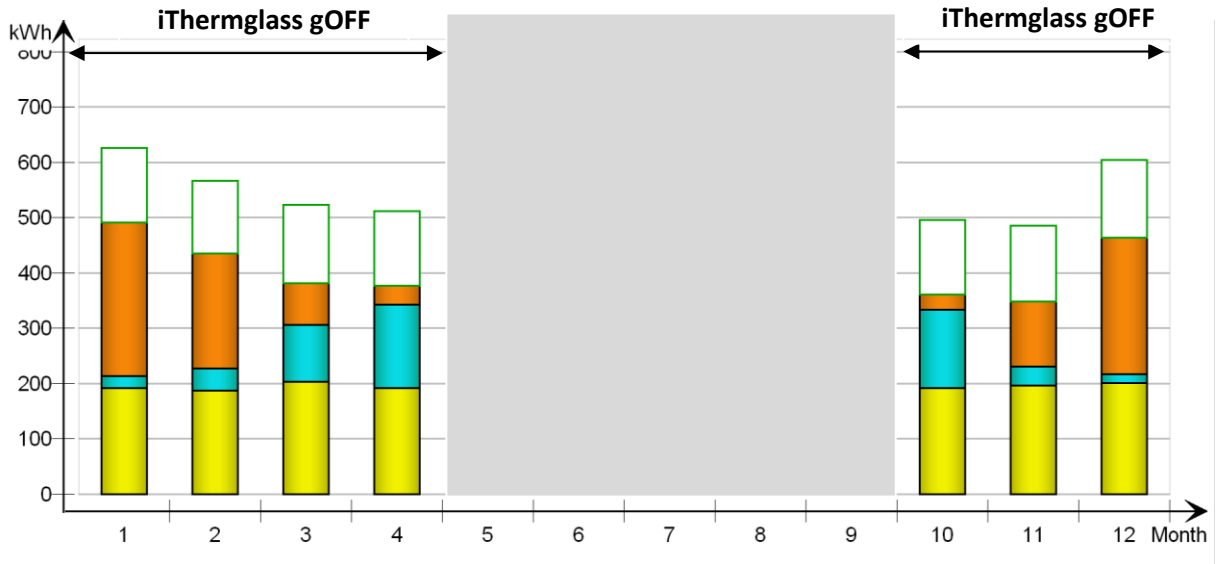


IMAGE 17:

SIMULATION 1B, MONTLY ENERGY CONSUMTION, MAY - SEPTEMBER

SIMULATION 1B, MONTHLY ENERGY CONSUMPTION, OCTOBER - APRIL (iThermglass gOFF)

Month	Facility electric			Facility fuel	Tenant electric
	Lighting, facility	Electric cooling	Electric heating	Domestic hot water	Equipment, tenant
	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)
1	192.2	21.3	277.9	0.0	134.6
2	187.6	40.3	207.6	0.0	131.3
3	203.1	103.2	75.5	0.0	142.1
4	192.0	151.1	34.2	0.0	134.4
10	191.9	141.6	27.5	0.0	134.4
11	196.1	34.8	117.2	0.0	137.3
12	201.2	16.5	247.0	0.0	140.8



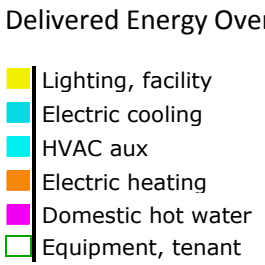


IMAGE 18:

SIMULATION 1B, MONTLY ENERGY CONSUMTION, OCTOBER - APRIL

COMPARISON OF ANNUAL ENERGY CONSUMPTION, SIMULATIONS GROUP 1

SIMULATION 1A, ANNUAL ENERGY CONSUMPTION (Reference Glass)

Delivered Energy Overview		Purchased energy		Peak demand
		kWh	kWh/m2	kW
	Lighting, facility	2342	23.4	0.8
	Electric cooling	3347	33.5	2.75
	Electric heating	813	8.1	1.21
	Domestic hot water	0	0.0	0.0
	Equipment, tenant	1639	16.4	0.56
	Grand total	8141	81.4	

SIMULATION 1B, ANNUAL ENERGY CONSUMPTION (iThermglass)

Delivered Energy Overview		Purchased energy		Peak demand
		kWh	kWh/m2	kW
	Lighting, facility	2342	23.4	0.8
	Electric cooling	1972.4	19.7	1.94
	Electric heating	986.9	9.9	1.35
	Domestic hot water	0	0.0	0.0
	Equipment, tenant	1639	16.4	0.56
	Grand total	6939		

SIMULATION 2A, SUMMER SOLSTICE (Reference Glass)

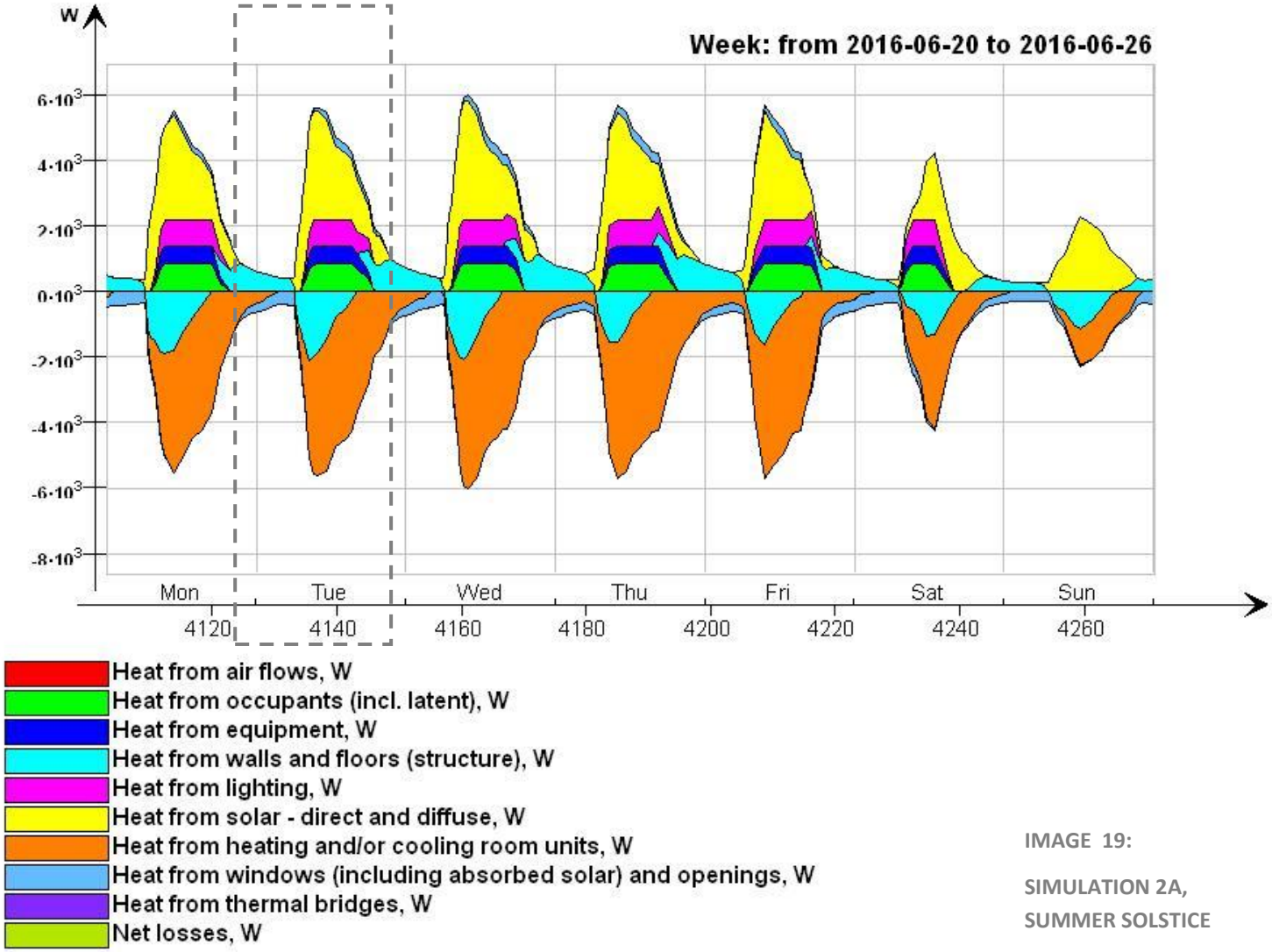


IMAGE 19:

SIMULATION 2A, SUMMER SOLSTICE

SIMULATION 2B, SUMMER SOLSTICE (iThermglass gON)

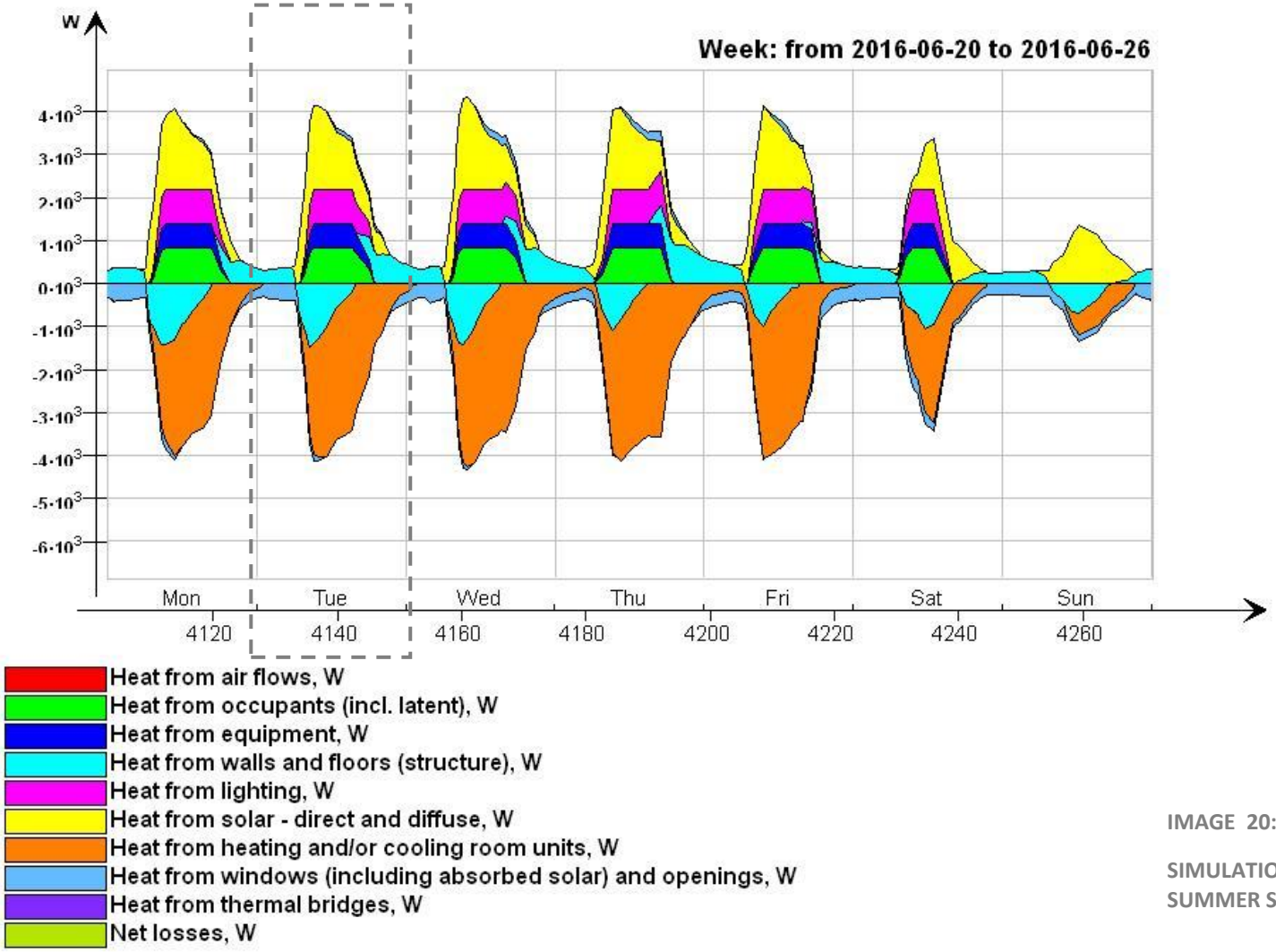


IMAGE 20:

SIMULATION 2B, SUMMER SOLSTICE

SIMULATION 2A, WINTER SOLSTICE (Reference Glass)

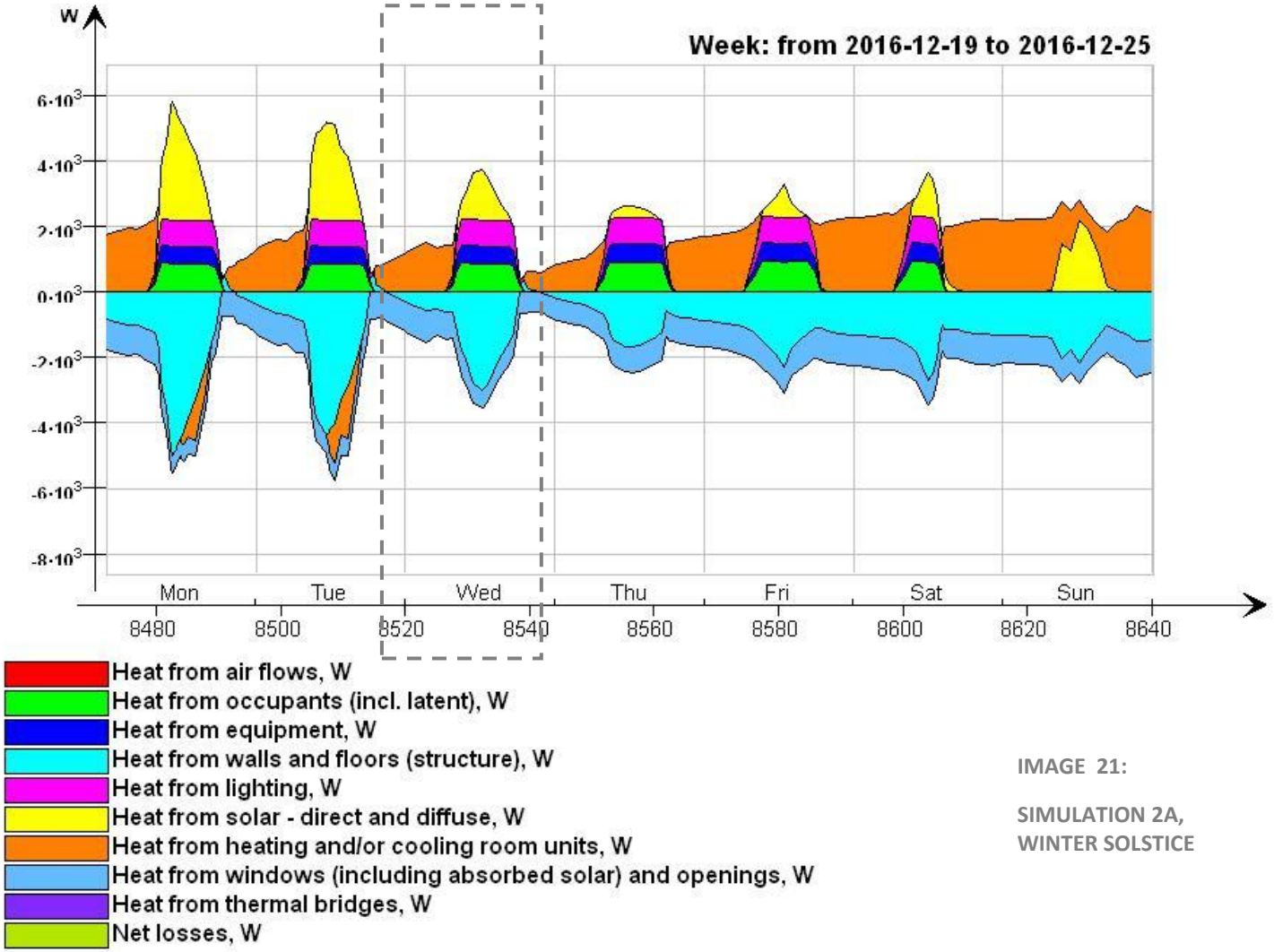


IMAGE 21:

SIMULATION 2A, WINTER SOLSTICE

SIMULATION 2B, WINTER SOLSTICE (iThermglass gOFF)

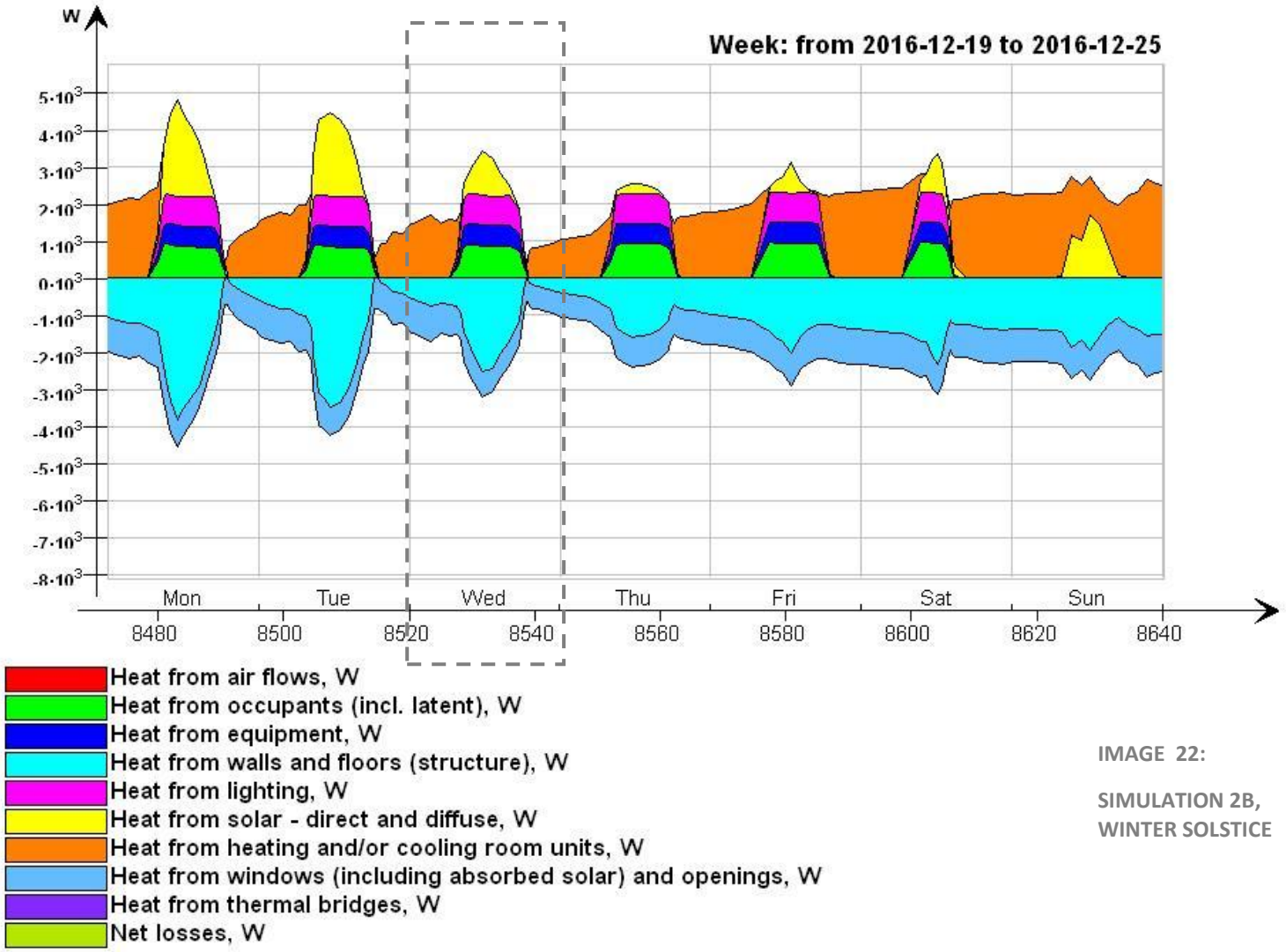
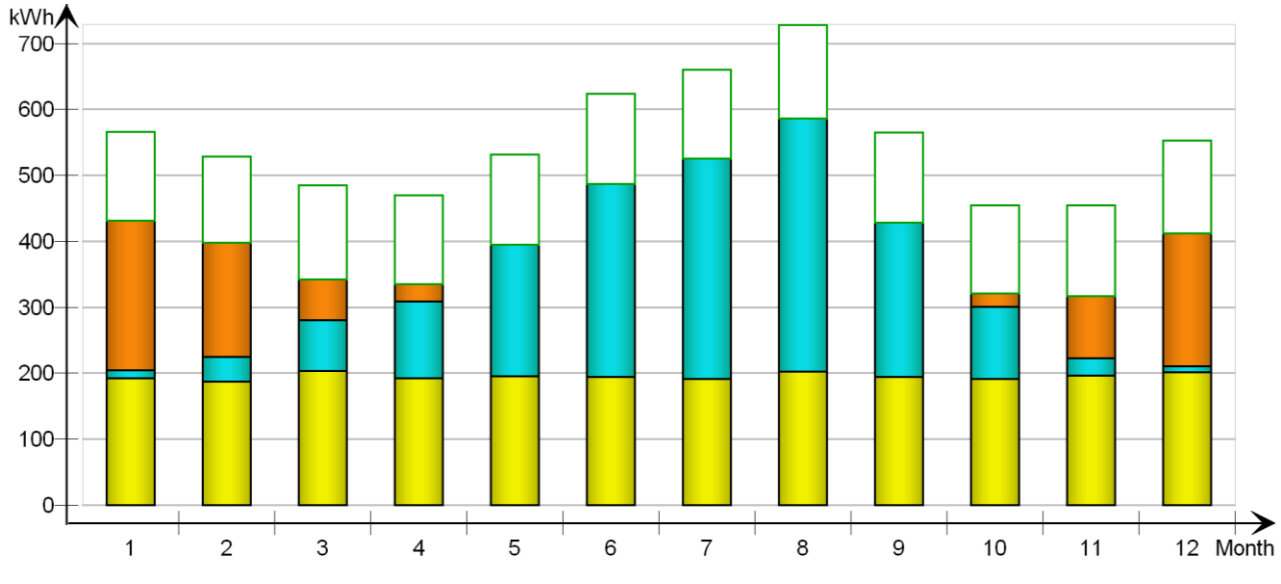


IMAGE 22:

SIMULATION 2B, WINTER SOLSTICE

SIMULATION 2A, MONTHLY ENERGY CONSUMPTION (Reference Glass)

Month	Facility electric			Facility fuel	Tenant electric
	Lighting, facility	Electric cooling	Electric heating	Domestic hot water	Equipment, tenant
	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)
1	192.6	12.1	226.8	0.0	134.8
2	187.3	37.1	173.0	0.0	131.1
3	203.4	76.9	61.7	0.0	142.4
4	192.1	116.5	26.6	0.0	134.5
5	195.1	199.4	0.0	0.0	136.6
6	194.6	292.4	0.0	0.0	136.2
7	191.8	333.8	0.0	0.0	134.2
8	202.9	384.1	0.0	0.0	142.0
9	194.6	234.2	0.0	0.0	136.2
10	191.6	109.4	20.0	0.0	134.1
11	196.3	26.2	94.3	0.0	137.4
12	201.5	8.7	201.2	0.0	141.1
Total	2343.8	1830.8	803.6	0.0	1640.6



Delivered Energy Overview

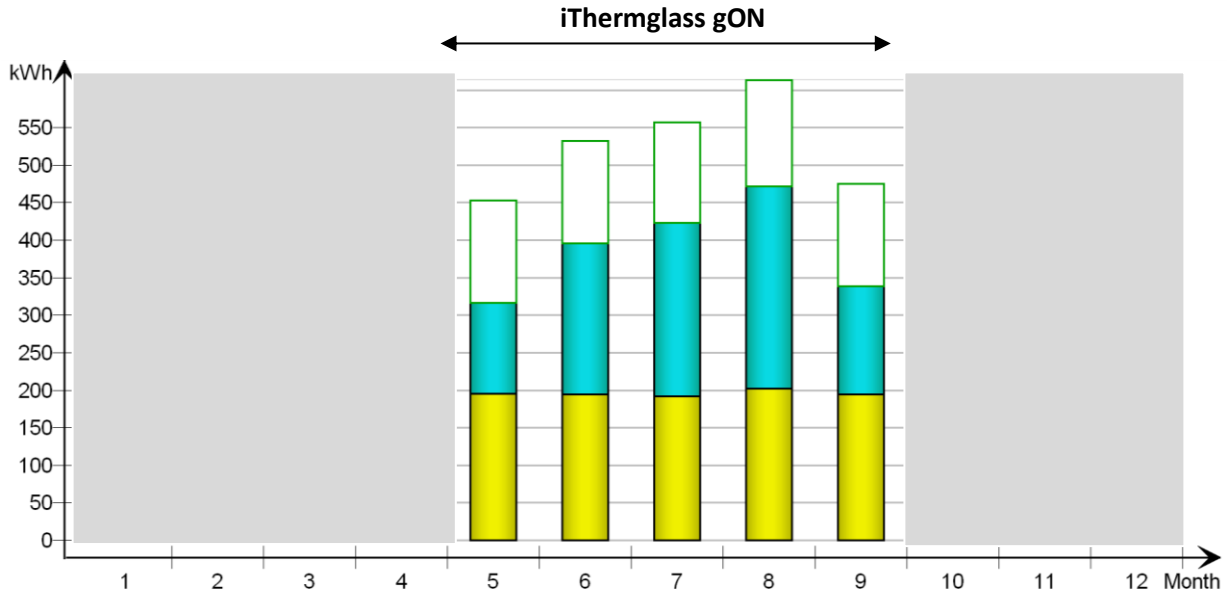
- Lighting, facility
- Electric cooling
- HVAC aux
- Electric heating
- Domestic hot water
- Equipment, tenant

IMAGE 23:

SIMULATION 2A, MONTHLY ENERGY CONSUMPTION

SIMULATION 2B, MONTHLY ENERGY CONSUMPTION, MAY - SEPTEMBER (iThermglass gON)

Month	Facility electric			Facility fuel	Tenant electric
	Lighting, facility	Electric cooling	Electric heating	Domestic hot water	Equipment, tenant
	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)
5	195.3	121.0	0.0	0.0	136.7
6	194.5	201.7	0.0	0.0	136.2
7	191.9	231.1	0.0	0.0	134.3
8	202.6	269.8	0.0	0.0	141.8
9	194.9	144.4	0.1	0.0	136.4



Delivered Energy Overview

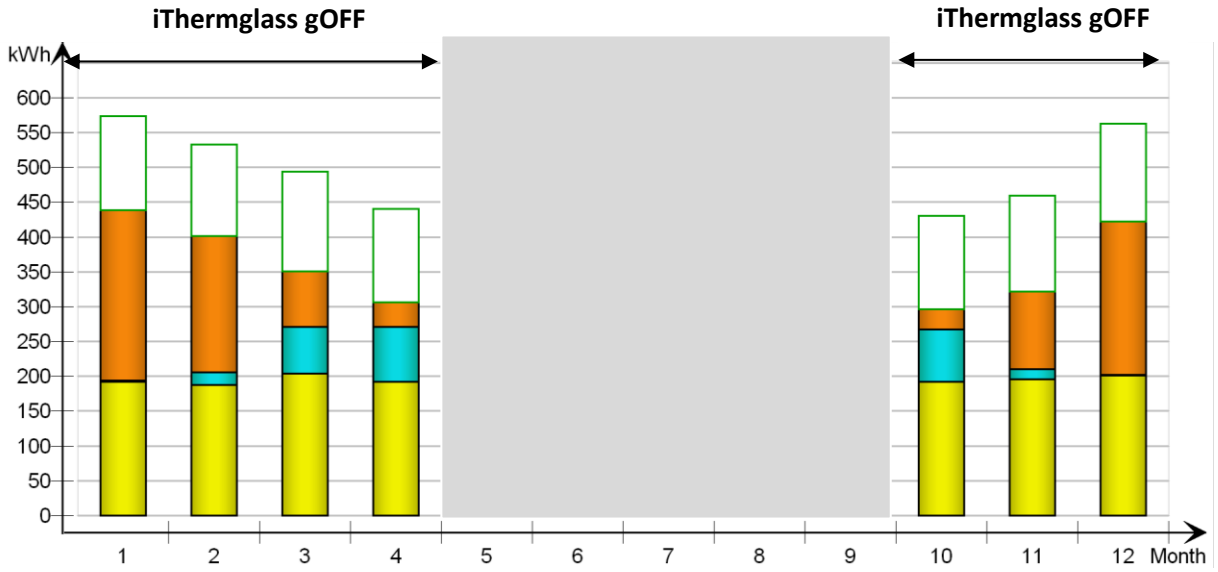
- Lighting, facility
- Electric cooling
- HVAC aux
- Electric heating
- Domestic hot water
- Equipment, tenant

IMAGE 24:

SIMULATION 2B, MONTHLY ENERGY CONSUMPTION, MAY - SEPTEMBER

SIMULATION 2B, MONTHLY ENERGY CONSUMPTION, OCTOBER - APRIL (iThermglass gOFF)

Month	Facility electric			Facility fuel	Tenant electric
	Lighting, facility	Electric cooling	Electric heating	Domestic hot water	Equipment, tenant
	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)
1	192.5	1.6	244.6	0.0	134.8
2	187.3	18.1	196.0	0.0	131.1
3	204.1	66.7	80.1	0.0	142.9
4	192.0	79.0	35.5	0.0	134.4
10	192.0	75.7	29.3	0.0	134.4
11	196.1	14.2	111.7	0.0	137.3
12	201.1	1.3	220.4	0.0	140.8



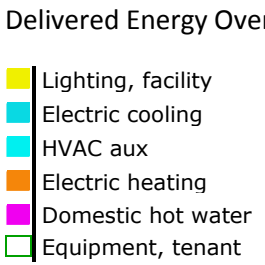


IMAGE 25:

SIMULATION 2B, MONTHLY ENERGY CONSUMPTION, OCTOBER - APRIL

COMPARISON OF ANNUAL ENERGY CONSUMPTION, SIMULATIONS GROUP 2

SIMULATION 2A, ANNUAL ENERGY CONSUMPTION (Reference Glass)

Delivered Energy Overview		Purchased energy		Peak demand
		kWh	kWh/m2	kW
	Lighting, facility	2344	23.4	0.8
	Electric cooling	1831	18.3	1.63
	Electric heating	804	8.0	1.11
	Domestic hot water	0	0.0	0.0
	Equipment, tenant	1641	16.4	0.56
	Grand total	6620	66.2	

SIMULATION 2B, ANNUAL ENERGY CONSUMPTION (iThermglass)

Delivered Energy Overview		Purchased energy		Peak demand
		kWh	kWh/m2	kW
	Lighting, facility	2344	23.4	0.8
	Electric cooling	1224.6	12.24	1.42
	Electric heating	917.7	9.2	1.15
	Domestic hot water	0	0	
	Equipment, tenant	1641	16.4	0.56
	Grand total			