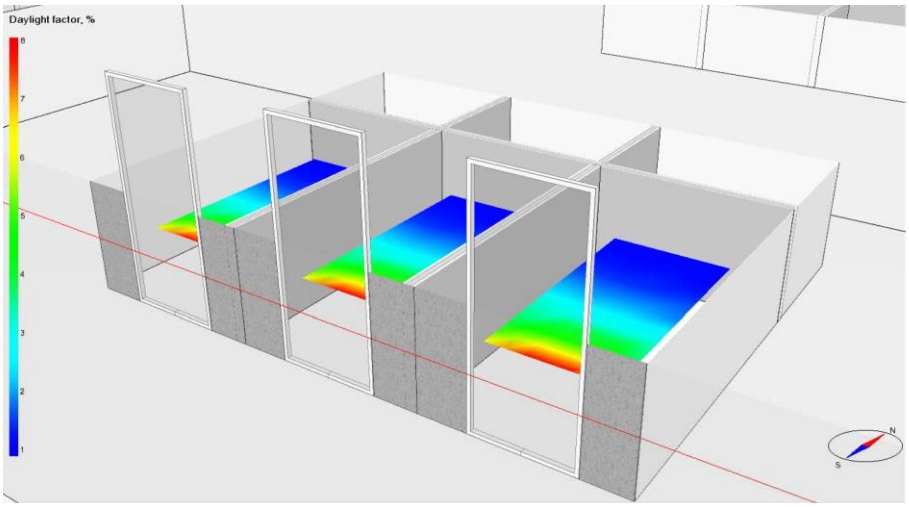
First generation of site-ZEB building simulation with performance data of existing Water Flow Glazing



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

Coordinator: Prof. Dr.-Ing. Dieter Brüggemann, University of Bayreuth, Germany
Tel: +49-(0)921-55-71 60, Fax: +49 (0) 921/55-71 65
Email: brueggemann@uni-bayreuth.de

European Commission
Horizon 2020
European Union funding
for Research & Innovation

InDeWaG

INDUSTRIAL DEVELOPMENT OF WATER-FLOW GLASS FAÇADE SYSTEMS

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

Start date: 1. September 2015 –**Duration** 42 months
Date of latest version of Annex I against which the assessment will be made: 17.07.2015

Coordinator: Prof. Dr. M. Willert-Porada, University of Bayreuth, Germany
Tel: +49-(0)921-55-72 00, Fax: +49 (0) 921/55-72 05
Email: monika.willert-porada@uni-bayreuth.de

D – 1.1		
Due date	01.02.2016	
Author(s)	Ümit Esiyok	
Workpackage No. and Leader	WP1 and B+G (Bollinger + Grohmann Consulting GmbH)	
Date released by WP leader	29.01.2016	
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	**First generation building simulation, heating and cooling energy demand, reference and WFG case, performance of the WFG, different climate zones, thermal performance of the building, daylight,**
Abstract	By the end of 2020, net zero energy buildings will be an obligation in European countries. This can be achieved by introduction of innovative building envelope systems. InDeWag is introduced as a solution for this issue regarding cost reduction and shortened industrial production of WFG (Water Flow Glazing) façade components. One of the first steps in order to study this innovation is investigation of the existing systems, with regard to thermal and daylighting performance, with the help of the simulation tools such as IDA ICE. First results show that heating and cooling demand can be different according to the climate, building shape-type, window configuration. Each climate region has different heating and cooling performance, that's why the definition of the water flow glazing configuration should be studied according to these different climates.

HISTORY			
Author	**Date**	**Related to WP/Task**	**Comments**
Ümit Esiyok	01.02.2016	1/1.1	

1. Content of Deliverable

a. *Incorporating the dynamic behavior of the fluid-filled façade units (measured data provided from WP 4 and WP 6, calculated from WP 2) into the design of facades*: There is no any measured data provided from related work packages. Because of that reason the inputs of the first simulations were defined during the weekly meetings with partners and assumptions. Description of the reference and WFG (Water flow Glazing) cases for the first generation simulation runs are summarized in the following two Tables: (Table 2, Table 3). Internal activated water filled building components are not investigated with first simulation runs. Current simulation runs aim to illustrate only the influence of the WFG Façade elements.

b. *Incorporating all relevant components of the building systems for heating, cooling, ventilation*: All relevant inputs of the heating, cooling and ventilation were described with project partners, for example; heating and cooling set temperatures or ventilation rates, building geometry and type of use.

In order to study the influence of Water-Flow Glazing (WFG) on indoor climate, four office rooms were defined, which are placed next to the two identical neighbor rooms. Three walls were defined as internal walls and one as an external wall, which is faced to four different orientations. The internal walls were assumed as adiabatic walls, which were placed next to the rooms with identical thermal conditions.

For the first simulation runs an office room is used due to its higher internal gains than residential building. Residential and other building types can be investigated in coming phases as well.

The investigated room has a height of 3 m with 10 m² floor area. The glazing element has a dimension of 3, 00 m* 1, 3 m. Other assumptions were listed in the simulation option tables (Table 2and Table 3).

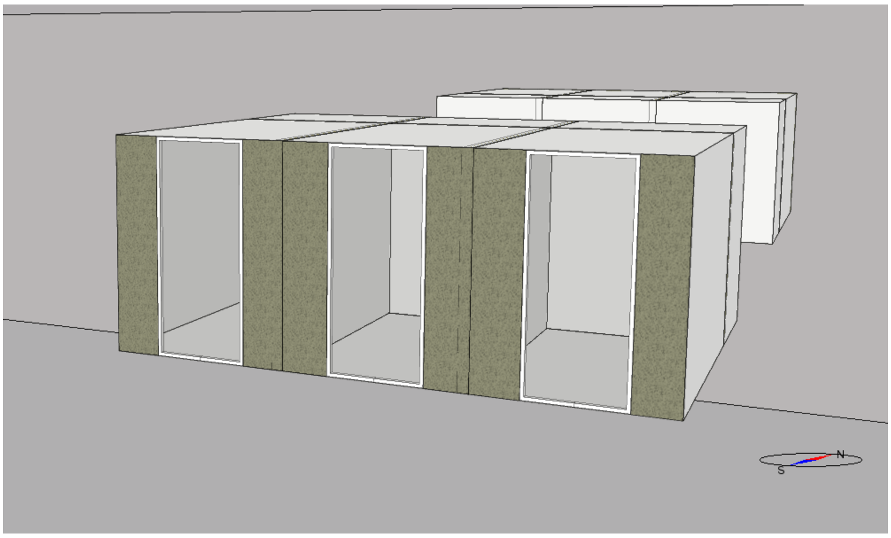


Figure 1: An office building block with three neighbor office zones on South

Building thermal zones:

The building was divided in 24 different Zones from each side, which consist of three external zones and three internal zones. The internal zones are circulation areas while external zones are office rooms (Figure 2).

Four office building rooms in the middle were analyzed regarding heating and cooling demand. In the future phases of project more thermal zones will be added according to the provided design parameters of selected or existing building.

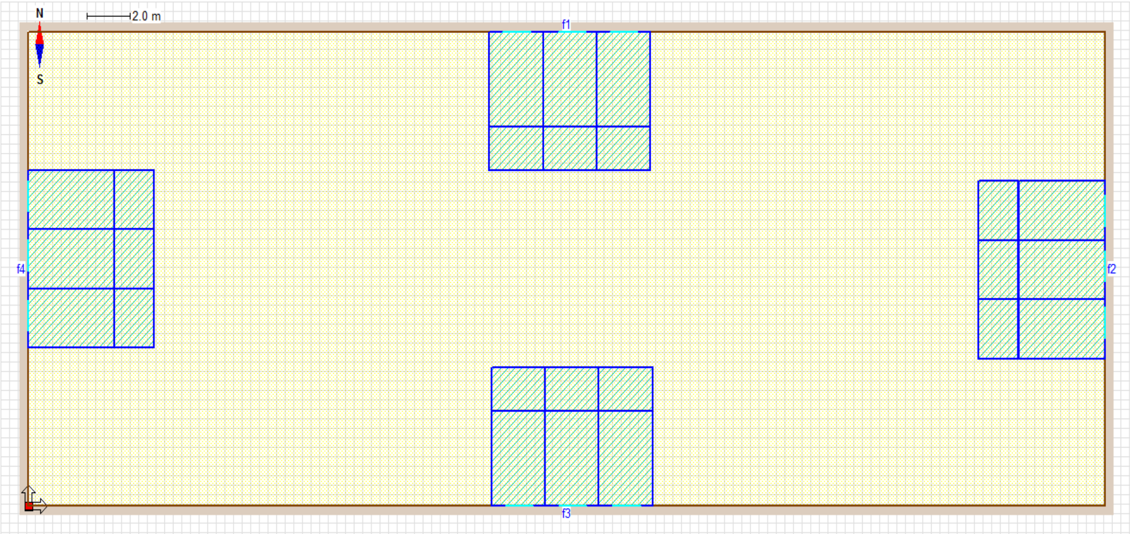


Figure 2: Thermal Zones-Floor plan

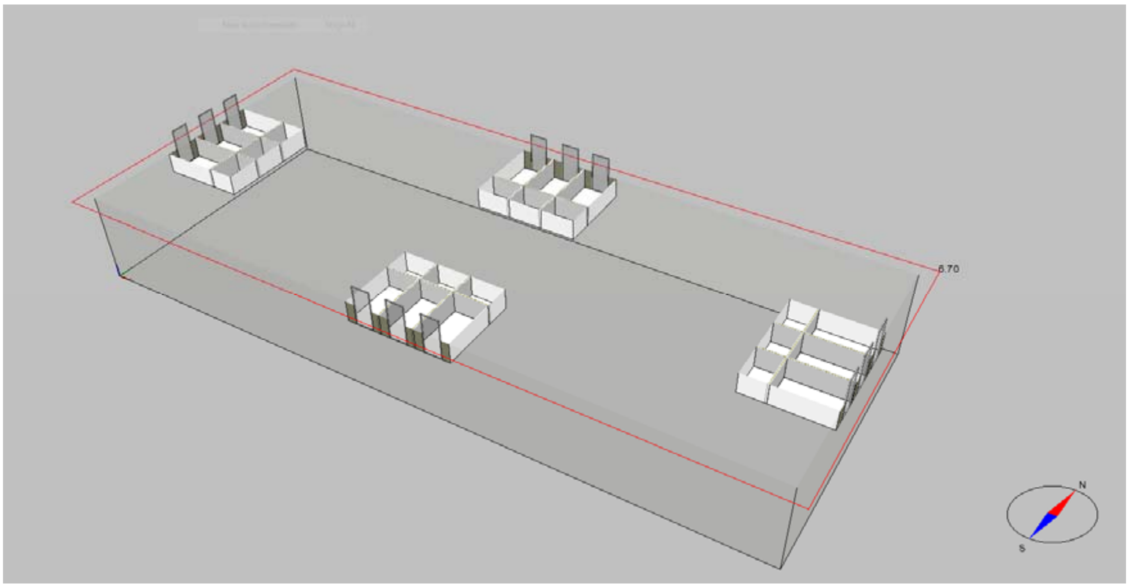


Figure 3: Thermal Zones-3D Model

Building components:

Following assumptions for the external wall, internal wall and ceiling-floor constructions were made:

Table 1: Properties of the building component

	External Wall	Internal Walls	Ceiling	Floor
U-Value [W/m²K]	0,25	0,6-0,7	2,3	2,3
Thickness [m]	0,22	0.15	0,175	0,175

The external walls and internal walls are light-weight constructions. Ceiling and floor constructions are made of heavy-weight constructions. Properties of Window are listed in the (Table 2 and Table 3)

Table 2: Simulation Options for the Reference Simulation

	Simulation 1	Simulation 2	Simulation 3
Location/climate	Madrid	Sofia	Frankfurt
Building Type	Office	Office	Office
Shape	Rectangle	Rectangle	Rectangle
Orientation of room (Window-WFG)	S,N,O and W	S,N,O and W	S,N,O and W
Room Area	10m²	10m²	10m²
Window/Floor Area	2/5	2/5	2/5
Facade (Transparent/Opaque area)	65% Transparent, 35% Opaque	65% Transparent, 35% Opaque	65% Transparent, 35% Opaque
Window	U-Value:1,1 W/m²K g-Value:0,43 Tvis: 0,46	U-Value:1,1 W/m²K g-Value:0,33 Tvis: 0,48	U-Value:1,1 W/m²K g-Value:0,33 Tvis: 0,48
External wall	U-Value:0,25 W/m²K	U-Value:0,25 W/m²K	U-Value:0,25 W/m²K
Internal gains	Occupancy (office): 0,1 User/m² with 5W/m², circulation area: 0,01 User/m² Equipment (Only Office): 7W/m² Lights(office):10 W/m² (Circ Area): 4W/m²	Occupancy (office): 0,1 User/m² with 5W/m², circulation area: 0,01 User/m² Equipment (Only Office): 7W/m² Lights(office):10 W/m² (Circ Area): 4W/m²	Occupancy (office): 0,1 User/m² with 5W/m², circulation area: 0,01 User/m² Equipment (Only Office): 7W/m² Lights(office):10 W/m² (Circ Area): 4W/m²
Schedule	09:00-18:00	09:00-18:00	07:00-18:00
Hygienic Air change	30 m³/h.person	30 m³/h.person	30 m³/h.person
Heating Cooling Set temperatures	20-26 °C	20-26 °C	20-26 °C

Table 3: Simulation Options for the WFG Case

	Simulation 1	Simulation 2	Simulation 3
Location/climate	Madrid	Sofia	Frankfurt
Building Type	Office	Office	Office
Shape	Rectangle	Rectangle	Rectangle
Orientation of room (Window-WFG)	S,N,O and W	S,N,O and W	S,N,O and W
Room Area	10m²	10m²	10m²
Window/Floor Area	2/5	2/5	2/5
Facade (Transparent/Opaque area)	65% Transparent, 35% Opaque	65% Transparent, 35% Opaque	65% Transparent, 35% Opaque
Window	U-Value:1,1 W/m²K g-Value: gON:0,235 gOFF:0,301 Tvis: 0,48	U-Value:1,1 W/m²K g-Value: gON:0,25 gOFF:0,33 Tvis: 0,525	U-Value:1,1 W/m²K g-Value: gON:0,25 gOFF:0,33 Tvis: 0,525
External wall	U-Value:0,25 W/m²K	U-Value:0,25 W/m²K	U-Value:0,25 W/m²K
Internal gains	Occupancy (office): 0,1 User/m² with 5W/m², circulation area: 0,01 User/m² Equipment (Only Office): 7W/m² Lights(office):10W/m² (Circ Area): 4W/m²	Occupancy (office): 0,1 User/m² with 5W/m², circulation area: 0,01 User/m² Equipment (Only Office): 7W/m² Lights(office):10 W/m² (Circ Area): 4W/m²	Occupancy (office): 0,1 User/m² with 5W/m², circulation area: 0,01 User/m² Equipment (Only Office): 7W/m² Lights(office):10 W/m² (Circ Area): 4W/m²
Schedule	09:00-18:00	09:00-18:00	07:00-18:00
Hygienic Air change	30 m³/h.person	30 m³/h.person	30 m³/h.person
Heating Cooling Set temperatures	20-26 °C	20-26°C	20-26°C

It is assumed that WFG Case has "iThermGlas" configuration for Madrid. Reference case configuration will be "ReferenceGlass", both derived from window catalogue. For Sofia and Frankfurt the window configuration is defined by project partner in Sofia, which is currently differs from window catalogue developed by UPM. In the coming phases of project after completing window catalogue the window configuration values can be altered in order to investigate their performance.

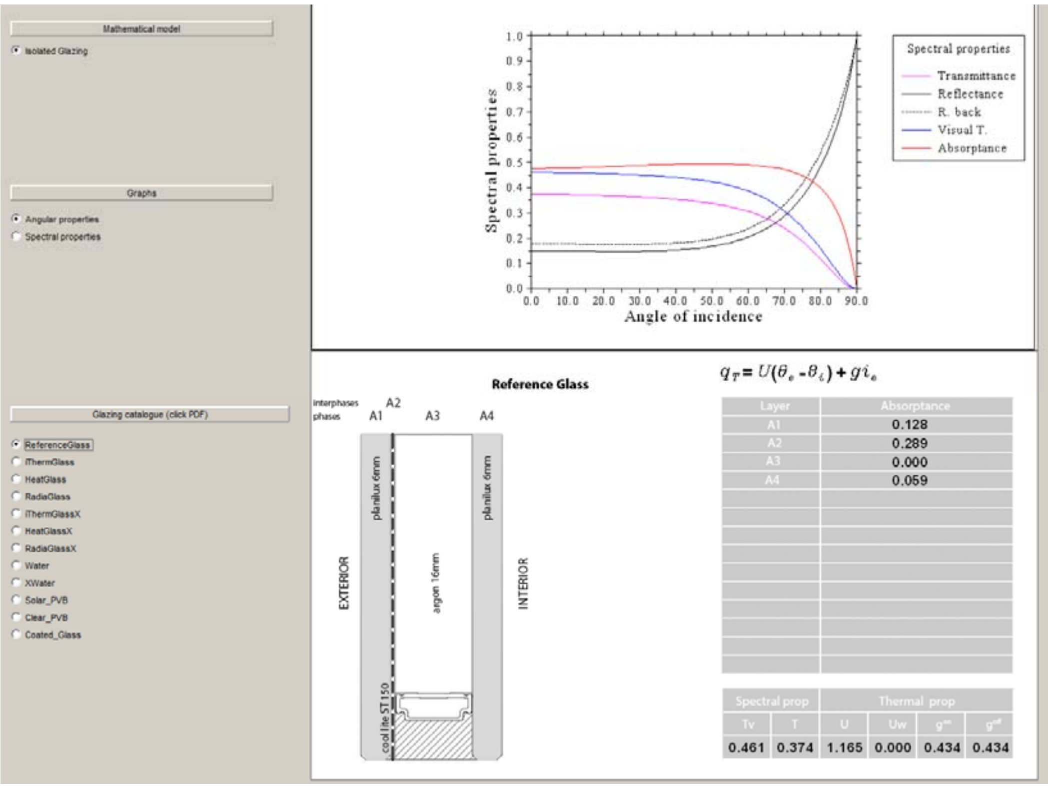


Figure 4: Reference case configuration for Madrid

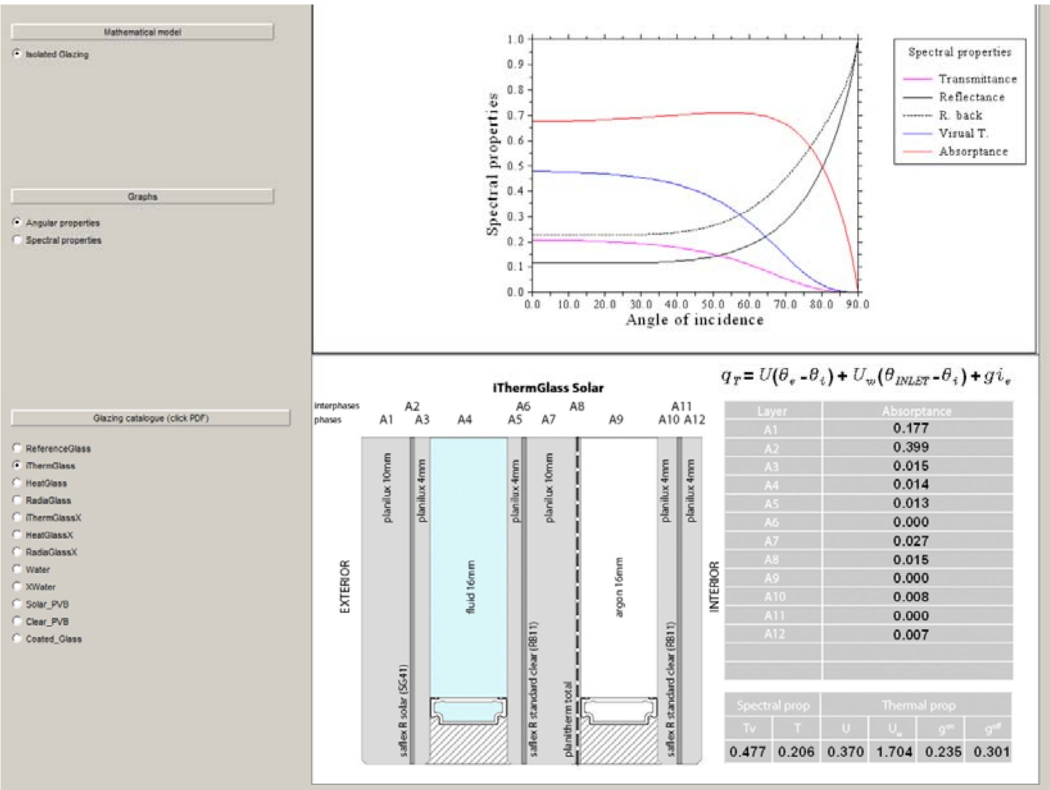


Figure 5: Glass configuration for Madrid „iThermGlass“

Definition of gON and gOFF:

gON: In Summer (from Mai till end of September)

gOFF: In Winter (from October till end of April)

G-Value modelling for the first generation simulations is defined with reduction of g-value, which illustrates that there is a flow in the glazing element (gON), without flow (gOFF). There is no any shading device or colorant for glazing/water assumed.

Daylight Studies:

Requirements of Daylight for the office rooms:

Daylight factor (D in %) is calculated with overcast sky conditions. For an office building, a workplace with 0.8 m height and 0.5 distances from each side of room was investigated, which was defined in the Standard EN 12464-1.

- Reflectance of the internal surfaces was assumed 0.5

The German Standard DIN 5034 requires a daylight factor more than 2% for more than 50 % of net floor area. The illuminance requirements for the office rooms should be 500 lux for the task area.

Optimal Daylight for a workplace should be greater than 2%: (D > 2%)

c. *Incorporating different climatic scenarios during the calendar year in different regions of the World. Three different climates in Europe were selected*: Sofia, Madrid and Frankfurt. Different climate zones in the World will be also studied during the next phases of the project. Three cities from different climate regions in Europe were selected for the first generation simulation studies: Sofia in Bulgaria, Madrid in Spain and Frankfurt in Germany.

Sofia (Bulgaria) is between continental and Mediterranean climates zones. As seen in the **Fehler! Verweisquelle konnte nicht gefunden werden.** and Figure 7Figure 7: Sofia Climate Data, in winter, the temperature can reduce down to -25°C; while in summer can increase up to 36°C.

Madrid (Spain) has a continental climate. The minimum temperature in winter is -5°C and maximum temperature in summer reaches almost 40°C. (Semi-arid cool climate)

Frankfurt (Germany) has a marine west coast climate like Sofia, which has no dry season with warm summers.

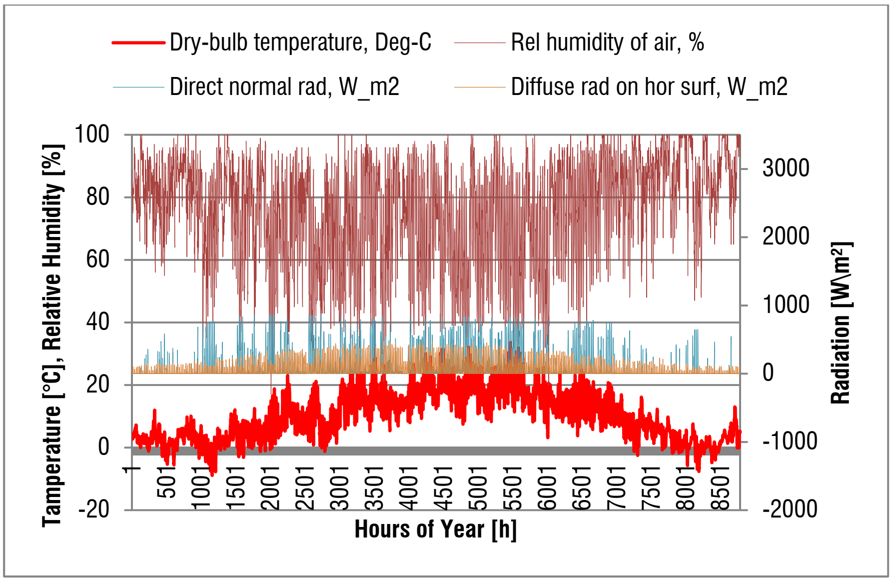


Figure 6: Frankfurt Climate Data

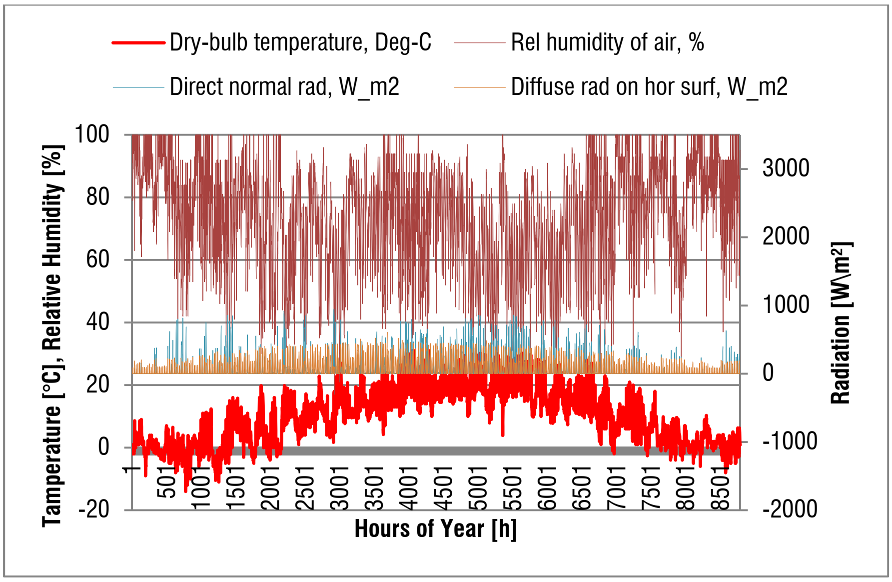


Figure 7: Sofia Climate Data

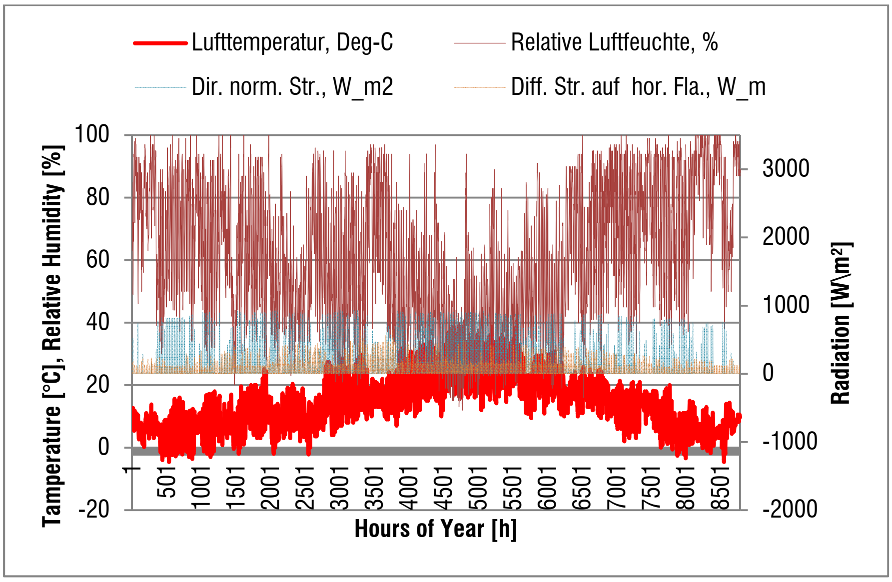


Figure 8: Madrid Climate Data

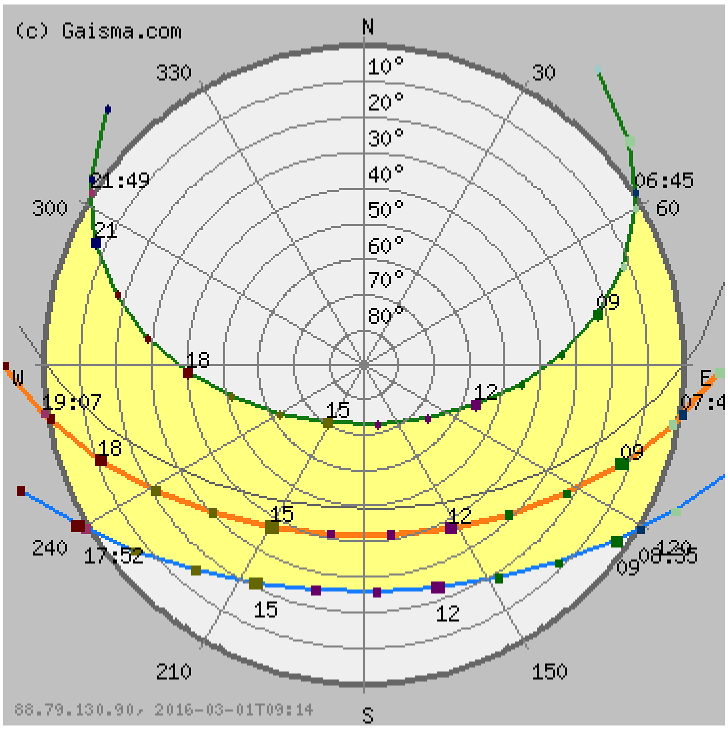


Figure 9: Sun path diagram of Madrid (Source: gaisma.com)

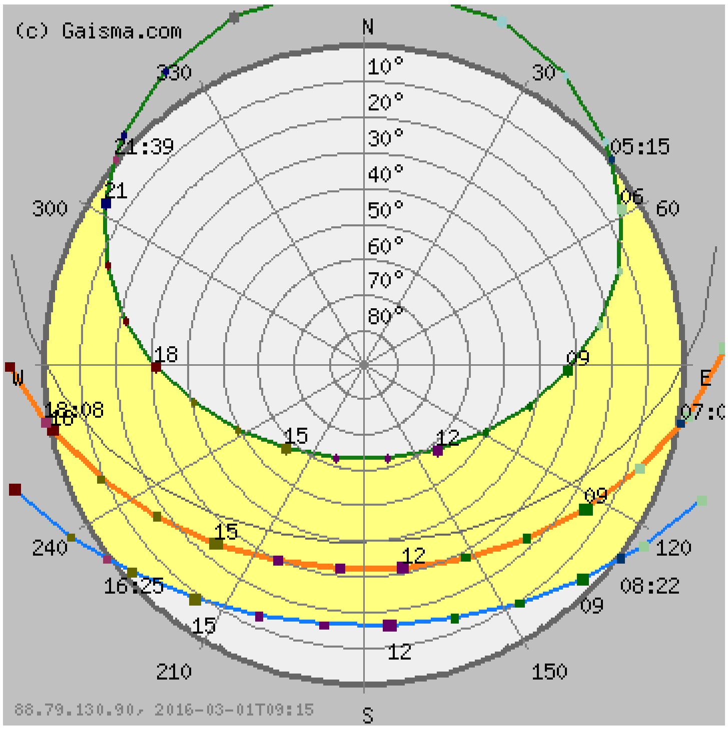


Figure 10: Sun path diagram of Frankfurt (Source: gaisma.com)

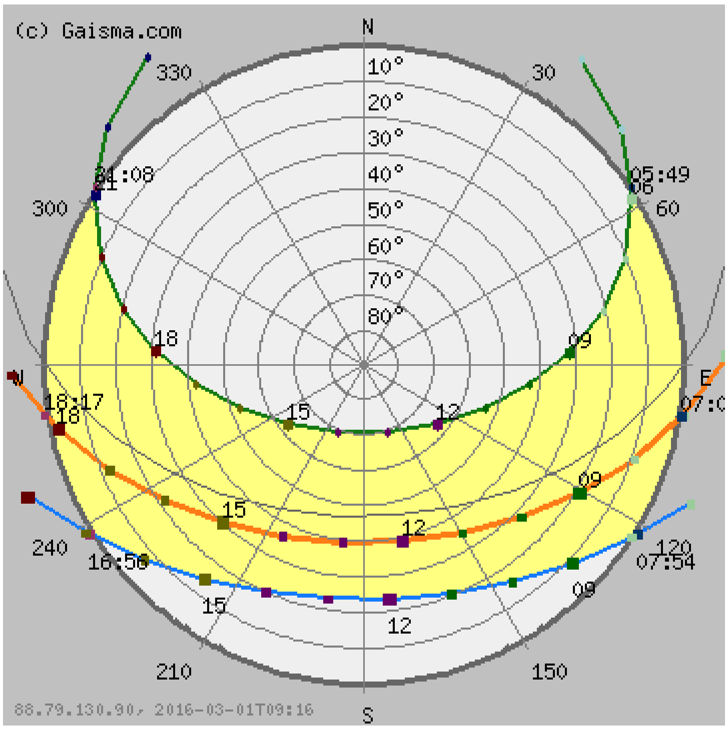


Figure 11: Sun path diagram of Sofia (Source: gaisma.com)

- **d.** *Results*: energy consumption in kWh/m² GFA/year, daylight comfort parameters (See Results and Discussion)
- ***e.*** *Selection of best building variants for the application of Fluid Flow Glazing as façade and interior radiant heating/cooling element*

First generation building simulation will be performed in order to give a prior performance of WFG elements on energy saving and create a base case simulation model for the further detailed simulations and define some inputs for the simulation tool to be developed in the future phases of the project. The Inputs of first generation building simulations were provided by simulation group of the project and assumptions, which are derived from existing Water Flow Glazing (WFG) systems or discussed during the weekly project meetings.

2. Results and Discussion

Energy Demand Results:

Table 4: Energy demand results (Delivered energy)

	Cooling Demand kWh/m²	Heating Demand kWh/m²
Reference Sofia	6,0	23,6
WFG Sofia	4,1	18,7
Reference Madrid	24,2	5
WFG Madrid	10,4	6,8
Reference Frankfurt	8,5	15,6
WFG Frankfurt	7,0	12,9

Madrid has the highest cooling energy saving with the help of the WFG Façade System, more than 50% comparing to the reference building. South building envelope has the highest impact on cooling energy demand more than 50% as well.

Cooling energy demand reduction with the activation of WFG façade element is almost 35% for a building in Sofia. The changes between reference and WFG cases in Frankfurt are not as high as in Sofia and Madrid.

Heating energy demand for investigated cities can be recovered by using activated internal building components (water filled internal glazing elements), which will be investigated in the future simulation runs.

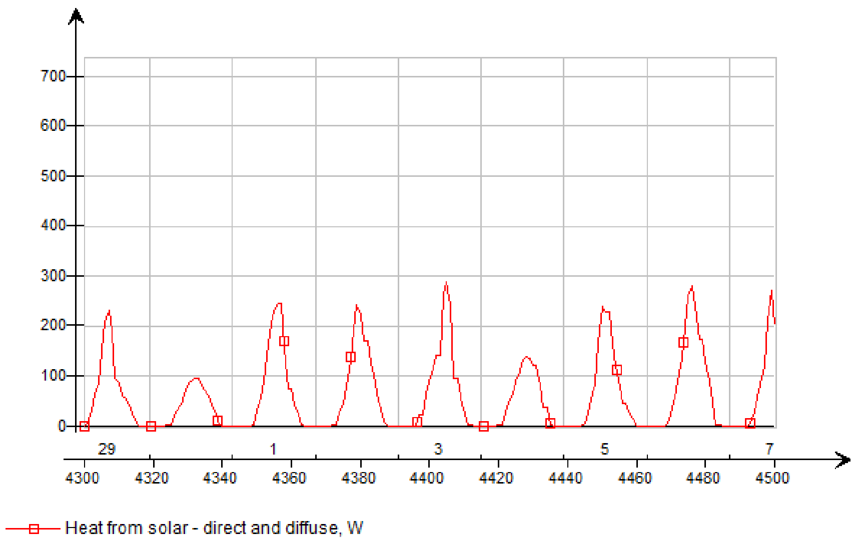


Figure 12: Solar heat gain for south oriented office room-Reference case Sofia

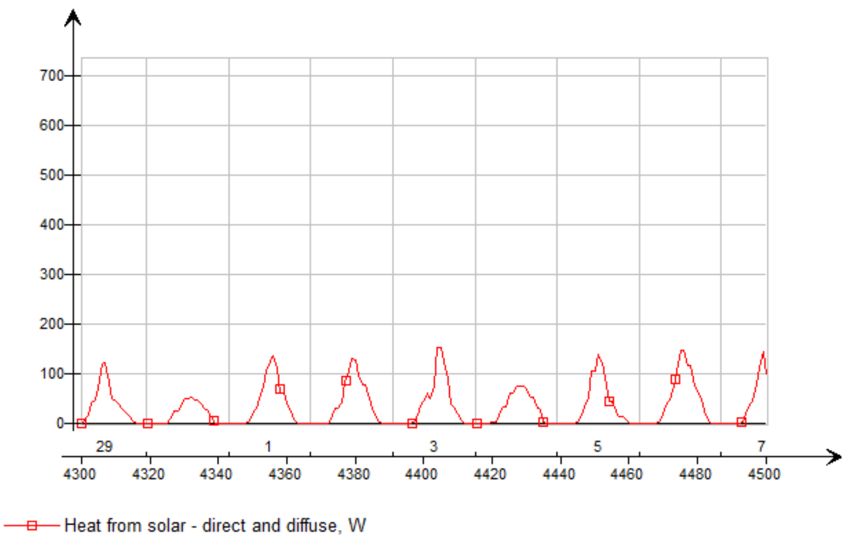


Figure 13 Solar heat gain for south oriented office room-WFG case Sofia

As seen in the graphs (Figure 122 and Figure 133) with the help of the Water Flow Glazing (WFG), solar heat gain through the south oriented transparent building envelope in Sofia is reduced almost half of the reference case. The result show only the influence of the activated WFG Glazing Element of external Wall regarding cooling loads; the Radiant internal Elements are going to be taken into account in coming simulation runs.

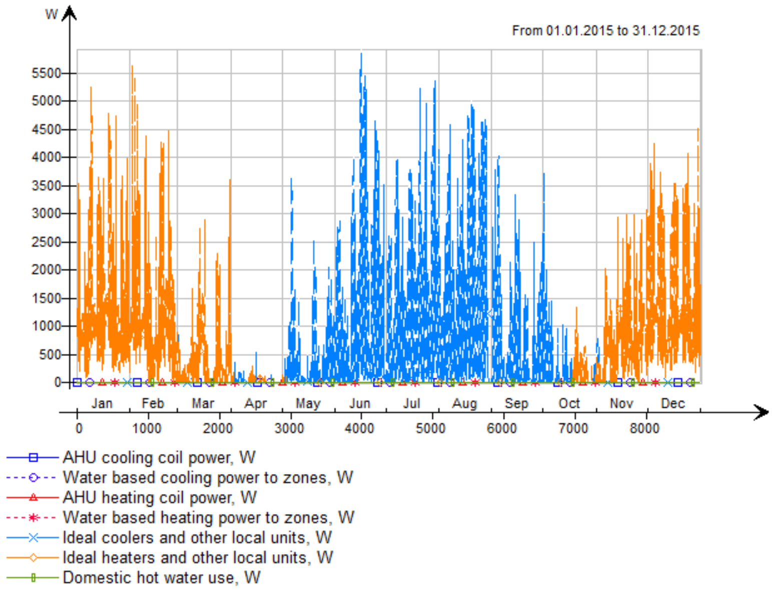


Figure 14: Total heating and cooling demand in a year for reference case-Sofia

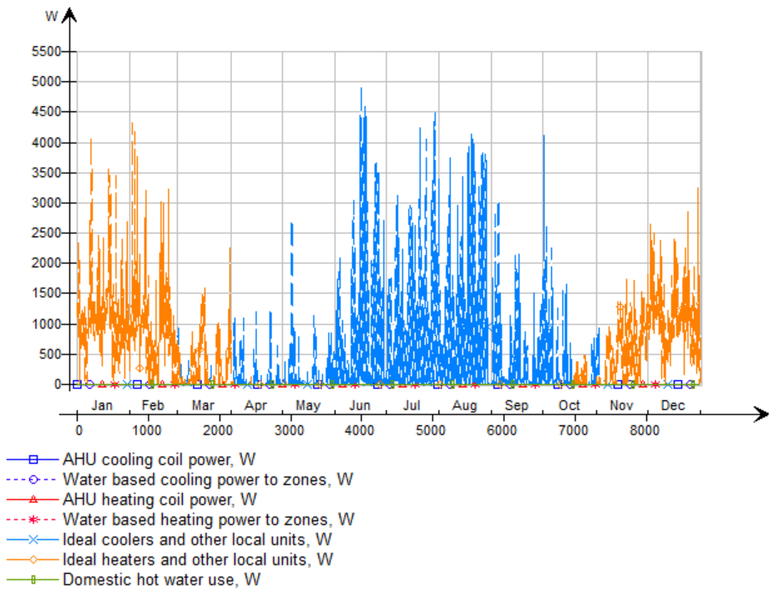


Figure 15: Total heating and cooling demand in a year for WFG facade case-Sofia

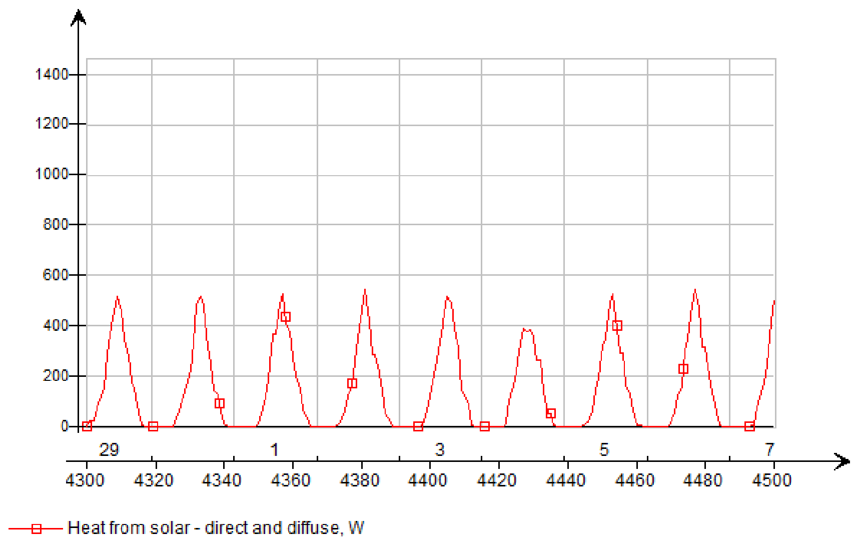


Figure 16: Solar heat gain for south oriented office room-reference case Madrid

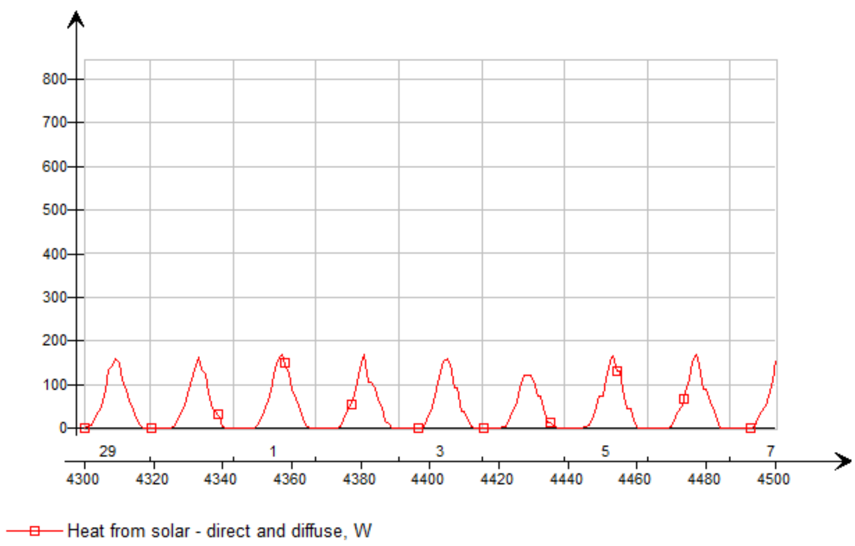


Figure 17: Solar heat gain for south oriented office room-WFG case Madrid

In Madrid the activated WFG façade has big influence on solar heat gain, more than 50 % solar heat gain is reduced on the South façade by activating WFG facade.

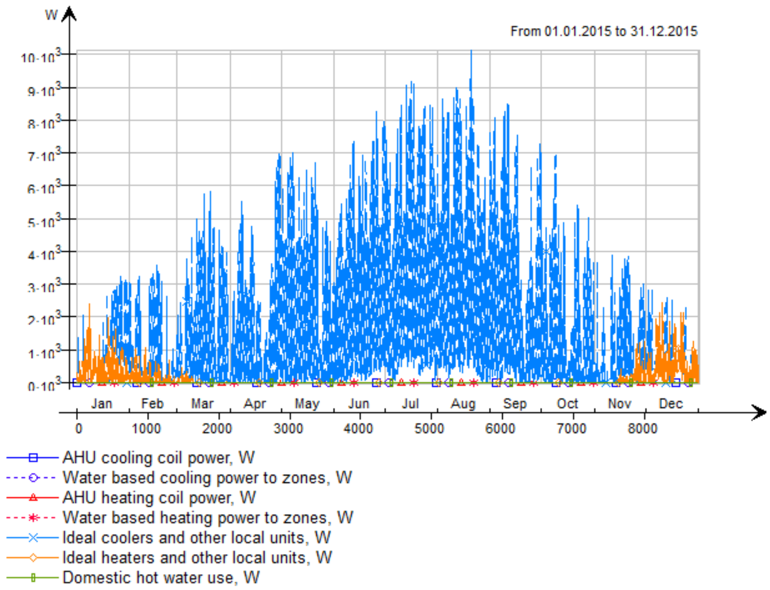


Figure 18: Total heating and cooling demand in a year for reference case-Madrid

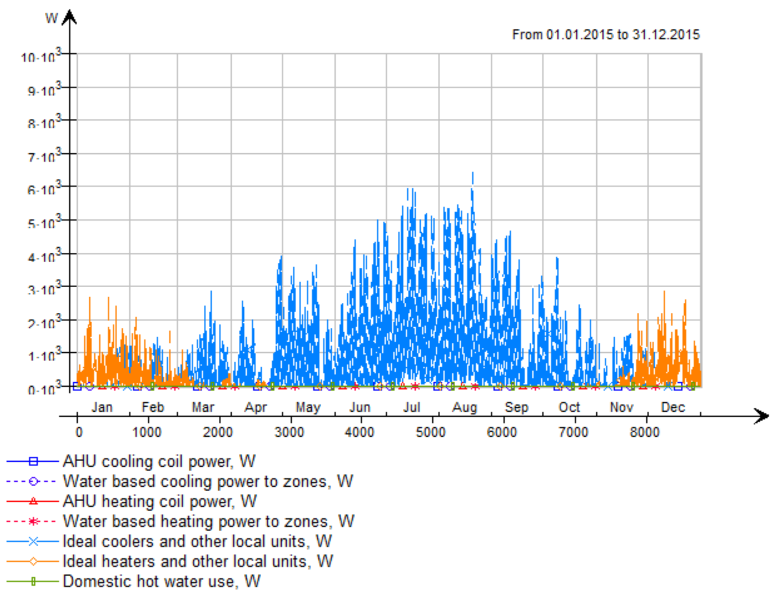


Figure 19: Total heating and cooling demand in a year for WFG facade case-Madrid

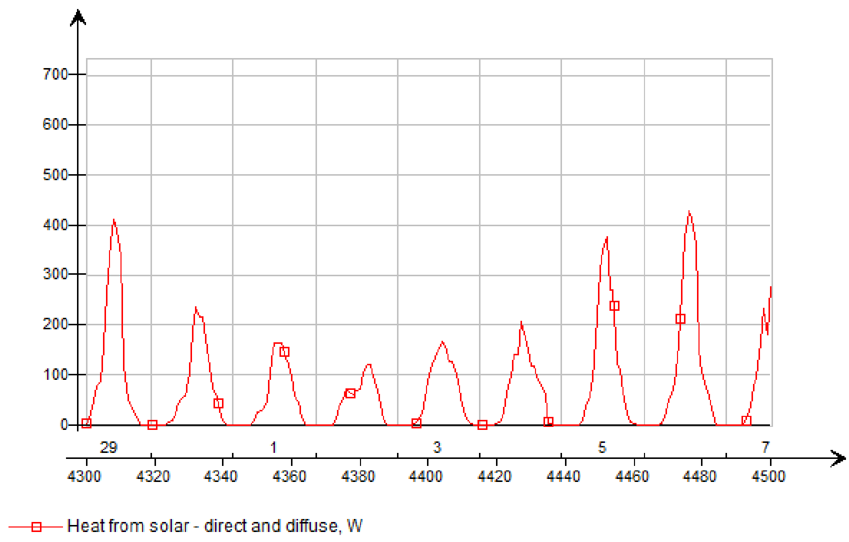


Figure 20: Solar heat gain for south oriented office room-reference case Frankfurt

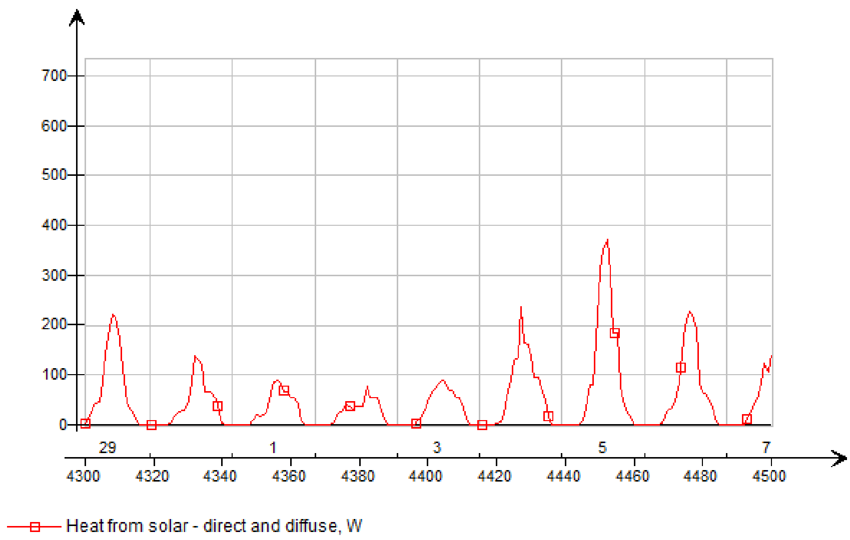


Figure 21: Solar heat gain for south oriented office room-WFG case Frankfurt

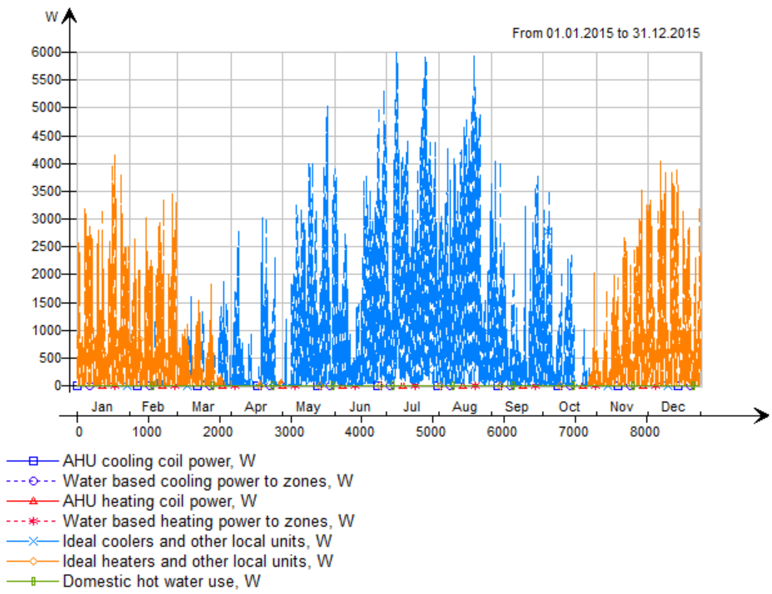


Figure 22: Total heating and cooling demand in a year for reference case-Frankfurt

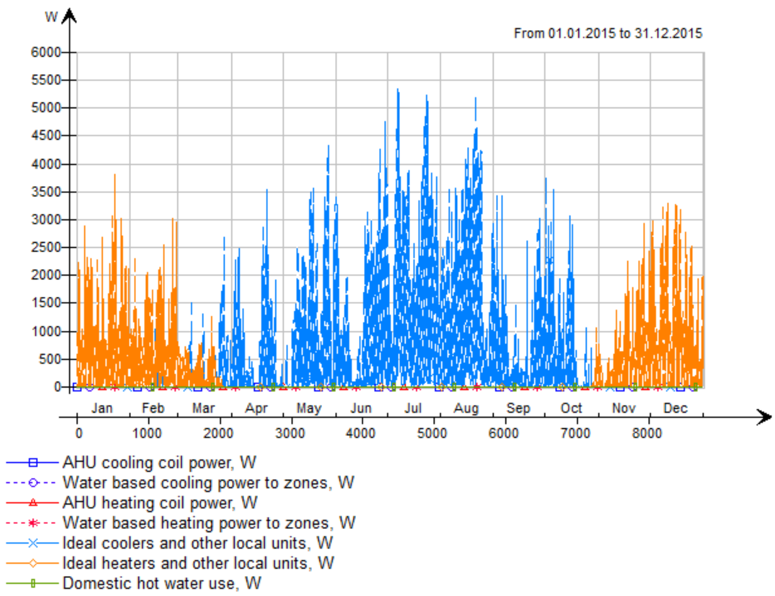


Figure 23: Total heating and cooling demand in a year for WFG facade case-Frankfurt

Daylight Results:

Figure 24: Daylight factor_Sofia Reference case

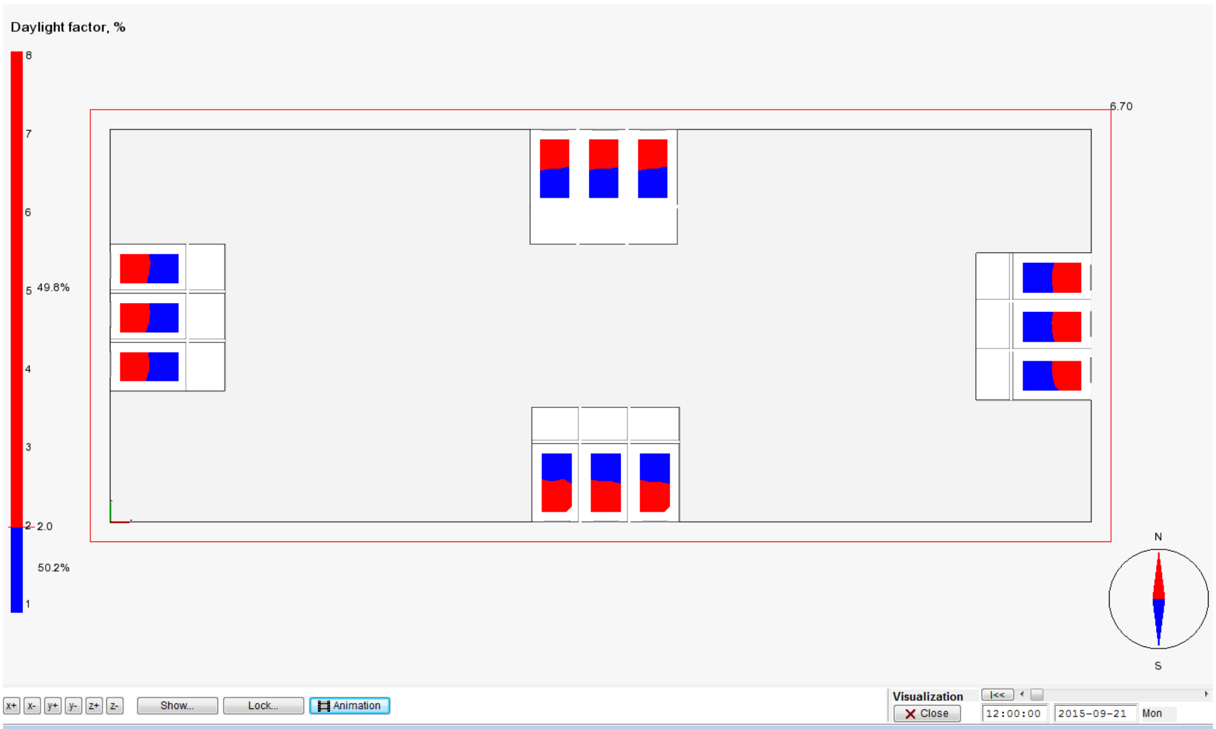


Figure 25: Percentage of area aboveDF: 2% daylight factor_Sofia Reference case

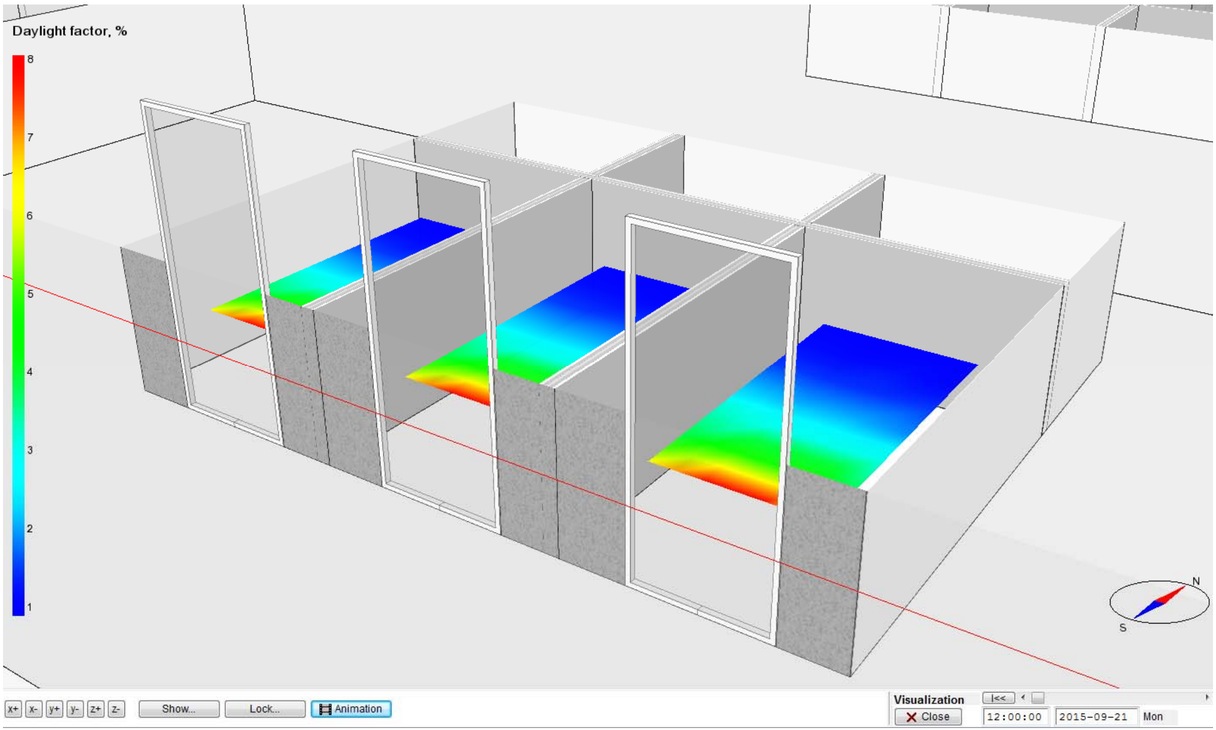


Figure 26: Daylight factor south office room_Sofia Reference case

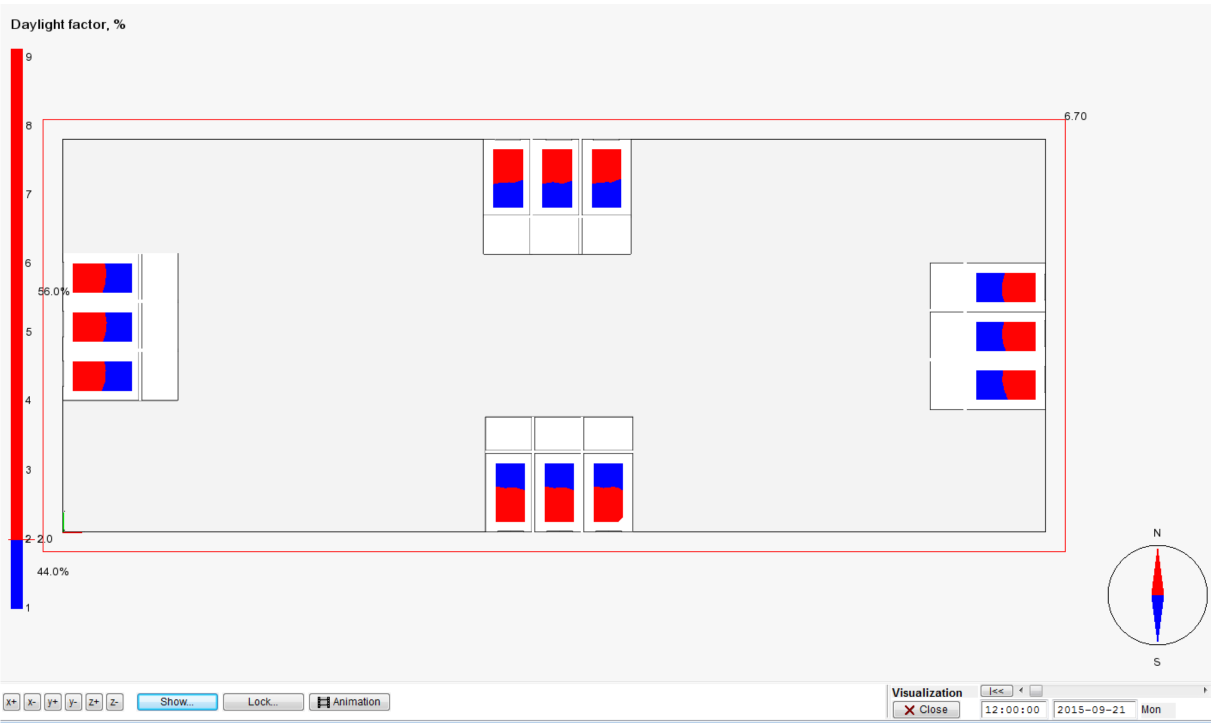


Figure 27: Percentage of area above DF: 2% daylight factor_Sofia WFG case

Figure 28: Daylight factor_ Madrid Reference case

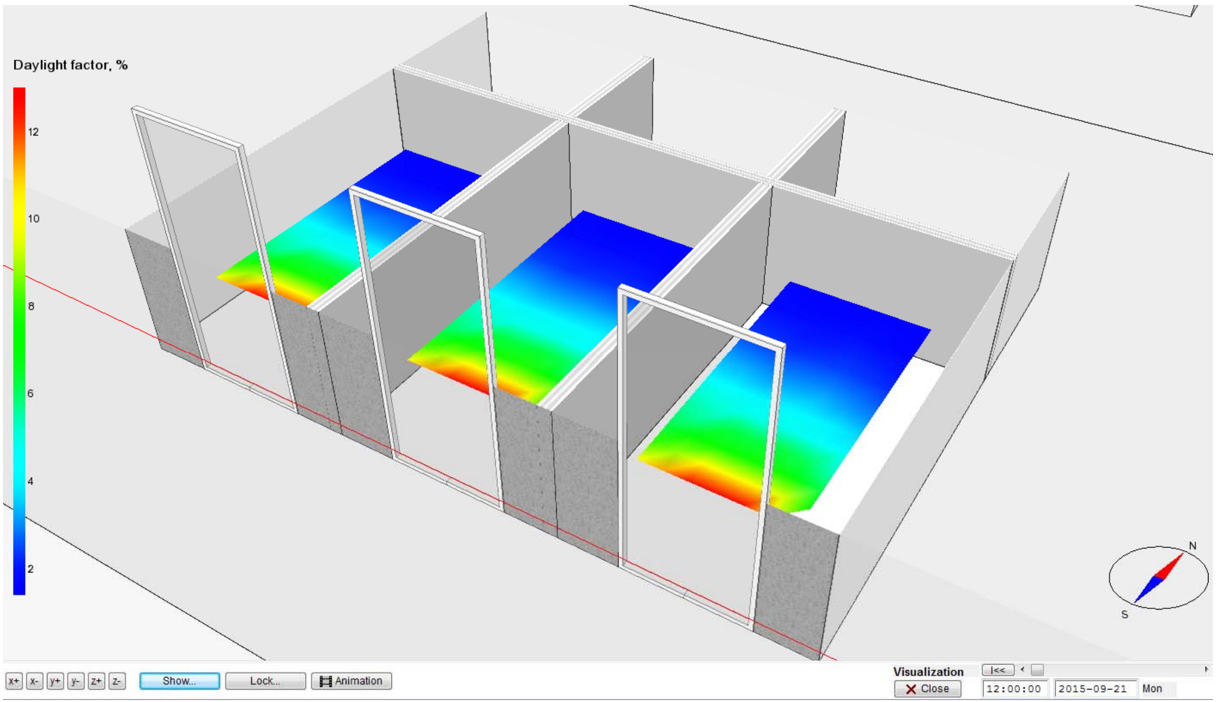


Figure 29: South office rooms Madrid Reference case

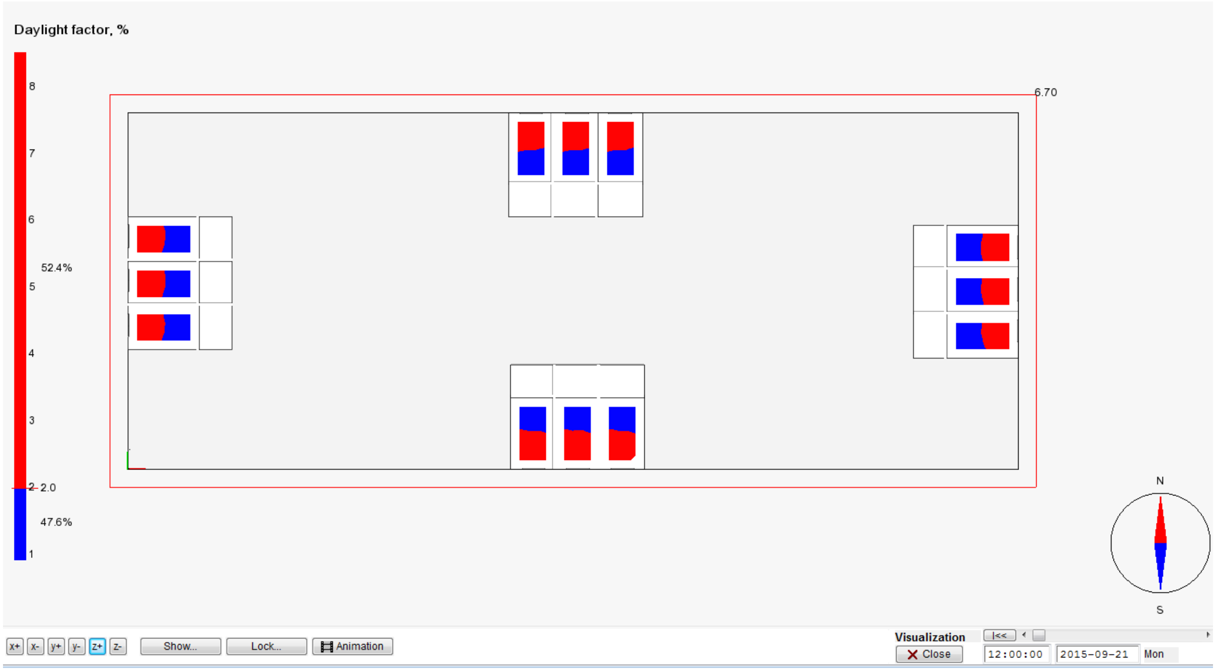


Figure 30: Percentage of area above 2% daylight factor-Madrid WFG case

The daylight results show that daylight factor requirements for all three cities do not met with the requirements in the EN 12464-1, which is mainly based on T-vis value of glazing element. A T-vis value of 0.48 for the WFG case illustrated that minimum T-vis value for all three cities should be not smaller than 0.50 in order to fulfill the percentage of net floor area above 2% Daylight Factor (DF). Water layer has no significant influence on daylighting since the visual transmittance values are similar like air or a gas layer, while the stored heat energy is transferred by activating water layer. Daylight performance can vary according to the different options of window area, window/floor area. Due to that reason each façade design should be separately investigated regarding daylighting performance.

In conclusion Water Flow Glazing (WFG) elements show better cooling performance in the warm climate regions or a building with high cooling loads in moderate climates.

Next simulation studies for the coming phases of project:

The glazing variants in the UPM Catalogue will be investigated according to the climate of cities. It is assumed that HeatGlass will be used for Sofia and Frankfurt, iThermGlass will be used for Madrid. The reference glazing elements will be the same configuration as in window catalogue but only without water layer.

In order to study selected three cities in detail, more variables are going to be investigated such as different window area and window/floor area, different building types, different control strategies for WFG and integration of the activated internal water filled components.

3. Degree of Progress

The Deliverable 1.1 is will be delayed due to the project start date, which has one month delay as well. It is estimated to finalize the Deliverable till end of the February 2016.

As it was planned, Deliverable 1.1 was sent end of February 2016.

4. Dissemination

This work is not published in any scientific journal or presented in a meeting.