Real demonstration results of BEM performance simulation using BIM-SPEED Toolset

Deliverable 4.2 – Energy Performance Report – Warsaw II demo

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BIM-SPEED
Harmonised Building Information Speedway for Energy-Efficient Renovation

This research project has received funding from the European Union's Programme H2020-NMBP-EEB-2018 under Grant Agreement no 820553.

ENERGY REPORT – WARSAW II

Deliverable 4.2 – Energy Performance Report

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Colophon

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Contents

Table of Figures

Table of tables

1. General information

1.1 Building description

Located beneath a busy Warsaw road is a former pedestrian underpass built in 1974. The city-owned structure will be renovated into a point of first contact for homeless people in the city including conference rooms, offices, as well as social and sanitary facilities which will provide people with meals and a place to bathe and rest. The main part of the existing structure is composed of reinforced concrete with pre-cast ceiling beams and will require new insulation and waterproofing to be installed as part of the renovation. As-built 2D drawings of the design are available. During the BIM-SPEED project new tools supporting design and energy simulation will be tested. Additionally, 3D Scan-to-BIM (Revit Plug-in) has been tested in terms of creating a structure model based on a point cloud.

Figure 1: 3D Model of the building

Following a brief summary of the demo general data

Table 1: General information

General information	
Location	Warsaw, Poland
Use category	healthcare
Building type	pedestrian underpass
Construction year	1974
Renovation year	2022
Number of floors	1
Number of apartments/units	No apartments

1.2 GIS and environmental data

In order to apply proper environmental conditions to BEM, EnergyPlus weather file for nearest available location was included, which is POL_Warsaw.123750_IWEC. The external temperatures imported into the BEM model are showed in the following graph.

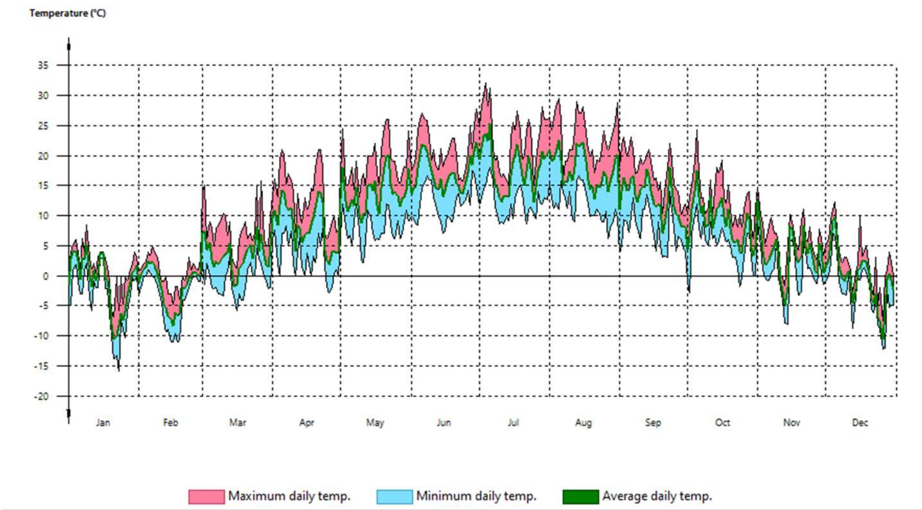


Figure 2: Minimum, maximum and average air temperature distribution

Error! Reference source not found. contains summary of general environmental data.

Table 2: General environmental data

General environmental data	
Location	Warsaw, Poland
Weather file	POL_Warsaw.123750_IWEC
Altitude [m]	100
Latitude [degrees]	52.1
Longitude [degrees]	21.1
Undistributed temp. of the soil [°C]	10.0
Network water temperature [°C]	15.0

2. Energy modelling

2.1 BIM-to-BEM procedure and software tools used

To complete the BIM-to-BEM process of Warsaw II demo case, the CYPETHERM-based procedure has been applied and the following tools have been used:

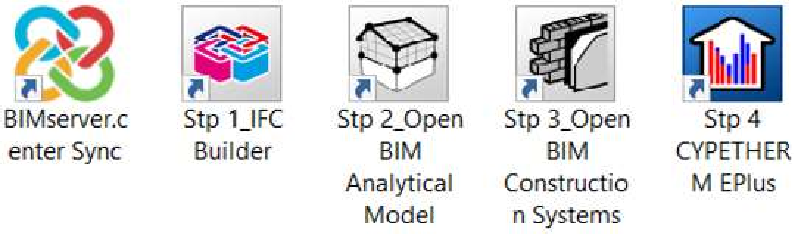


Figure 3: Software tools used to complete the BIM-to-BEM procedure

The BIM model was developed with Revit software and a proper .ifc file was exported directly with the tool's utilities. Following the BimSpeed guidelines, the .ifc file was uploaded to BIMserver.center platform using the Ifc Uploader provided by CYPE. Then the Open BIM Analytical Model was used to generate the analytical model of the building. A few adjustments have been required:

- a slight geometry simplification on both sides of underground entrances
- assumption that underground open passage won't be modelled as it is not a heated space

Last step in Open BIM Analytical Model was to create thermal spaces and assign them into groups differentiating by the room purpose and usage profile. The analytical model, once generated, has been exported once again in BIMserver.center and the project has been synchronized to be open within the Open BIM Construction Systems for the characterization of the building elements under the thermal point of view, defining all types of external and internal partitions, layer by layer, providing specific physical properties for each of them.

Model updated with construction data was uploaded once again to platform and fetched into Cypetherm Eplus, in order to complete the BEM with all thermal boundary conditions (e.g. rooms temperature profiles, lighting, ventilation, and occupancy) and the HVAC systems.

2.2 Auditing procedures and data collection

Draft Building Information Model for the building was developed during the project. The gathering of the data was performed through the energy audit and documents check.

2.3 Description of BEM's technical features

2.3.1 Envelope components and materials

This paragraph summarises the construction systems implemented within the Warsaw II BEM to characterise the thermal behaviour of the building. Envelope and internal partitions data were collected from buildings documentation and aggregated into Energy data collection spreadsheet. Gathering partitions data needed for BEM creation made the process faster and more reliable. Table 3 summarises all the materials implemented within the BEM.

Table 3: Materials

Layers					
Material	e	ρ	λ	RT	Cp
Plaster	1.00	150.00	0.400	0.03	1000.00
Gypsum fibre board	1.25	1150.00	0.320	0.04	1000.00
_Mineral wool	7.50	160.00	0.068	1.11	1300.00
_Mineral wool	8.50	160.00	0.077	1.11	1300.00
_Mineral wool	9.50	160.00	0.086	1.11	1300.00
_Mineral wool	11.50	160.00	0.104	1.11	1300.00
_Mineral wool	6.50	160.00	0.059	1.11	1300.00
_Reinforced concrete	25.00	2400.00	1.417	0.18	1000.00
HPL	2.00	1800.00	1.000	0.02	1000.00
_Brick 12	12.00	800.00	0.700	0.17	840.00
_Reinforced concrete	42.00	2400.00	2.323	0.18	1000.00
_Glass wool	20.00	250.00	0.180	1.11	840.00
_Reinforced concrete	30.00	2400.00	2.323	0.13	1000.00
_Reinforced concrete	67.00	2400.00	3.797	0.18	1000.00
_Glass wool	8.00	250.00	0.072	1.11	840.00
Air gap	26.00	2300.00	0.542	0.48	1008.00
Wood wool	5.00	60.00	0.057	0.88	800.00
Fleece	1.00	2300.00	0.100	0.10	1000.00
Concrete – Cast in place	7.00	2300.00	1.300	0.05	750.00
_Glass wool	4.00	250.00	0.036	1.11	840.00

Used abbreviations			
e	Thickness cm	RT	Thermal resistance (m²·K)/W
ρ	Density kg/m³	Cp	Specific heat J/(kg·K)
λ	Thermal conductivity W/(m·K)		

Within Table 4 all the construction systems created for the Warsaw II BEM using the Open BIM Construction Systems tool and stored within a dedicated library linked to the workflow on BIMserver.center have been reported.

Table 4: Construction systems

External Walls_Reference name	**Layers**	**Thickness [cm]**	
Data accuracy	**every material present**	**±1 cm**	**±1 cm**
Facade	glass wool	20	60
	reinforced concrete	40	
	air gap	6	
	ceramic facing	2	
Curtain Wall	-		15
Internal Walls_Reference name	**Layers**	**Thickness [cm]**	
Prefabrykaty żelbetowe 280	plaster	1	28
	reinforced concrete	25	
	HPL	2	
GK110	plaster/fleece/HPL	1	11

	gypsum fibre board	1,25	
	mineral wool	6,5	
	gypsum fibre board	1,25	
	plaster/fleece/HPL	1	
GK120	plaster/fleece/HPL	1	12
	gypsum fibre board	1,25	
	mineral wool	7,5	
	gypsum fibre board	1,25	
	plaster/fleece/HPL	1	
GK130	plaster/fleece/HPL	1	13
	gypsum fibre board	1,25	
	mineral wool	8,5	
	gypsum fibre board	1,25	
	plaster/fleece/HPL	1	
GK140	plaster/fleece/HPL	1	14
	gypsum fibre board	9,5	
	mineral wool	7,5	
	gypsum fibre board	1,25	
	plaster/fleece/HPL	1	
GK160	plaster/fleece/HPL	1	16
	gypsum fibre board	11,5	
	mineral wool	7,5	
	gypsum fibre board	1,25	
	plaster/fleece/HPL	1	
Underground Walls_Reference name	**Layers**	**Thickness [cm]**	
SZ1	brick	12	74
	reinforced concrete	42	
	glass wool	20	
SZ2	brick	12	62
	reinforced concrete	30	
	glass wool	20	
Slab on Grounf Floor_Reference name	**Layers**	**Thickness [cm]**	
PZ2	fleese	1	37,00
	Concrete cast in place	7	
	glass wool	4	
	reinforced concrete	25	
Roofs_Reference name	**Layers**	**Thickness [cm]**	
PZ1	reinforced concrete	67	106,00
	glass wool	8	
	air gap	26,00	

	wood wool suspended ceiling	5,00	
Reference name	**Door type**	**Thermal transmittance [W/m2K]**	
Data accuracy	**-**	**±0,01**	
Drzwi-korytarz-jednoskrzydłowe-wpuszczane	wood - internal	2,19	
Drzwi-jednoskrzydłowe-panelowe	wood -internal	2,19	
Drzwi-przeszklone	glass – external	0,43	

2.3.2 HVAC systems

Regarding the HVAC systems, the building is characterised by a district heating connection.

There are several different types of thermal zones in the modelled building.

Table 5: Thermal zones

Thermal zone	Space classification	Operational conditions *	Min comfort temperature [°C]	Max comfort temperature [°C]	DHW demand [l/day]	Ventilation rates [ACH]
Zone 1 - Workplace	Occupied	Heated and Cooled	20	20	7	2
Zone 2 – Cloakrooms and shower rooms	Occupied	Heated only	24	24	68	5.5
Zone 3 – Communication, Stockrooms, cleaning storages, technical rooms, Toilets	Occupied	Heated only	20	20	16	2.5
Zone 4 – Rooms 37,52	Occupied	n.r.	19	19	2	2
Zone 5 – Room 51	Occupied	n.r.	18	18	2	2
Zone 6 – Room 50	Occupied	n.r.	17	17	n.r.	2
Zone 7 – Room 49	Occupied	Heated only	16	16	n.r.	2
Zone 8 – Rooms 65,66	Occupied	Heated and Cooled	16	16	n.r.	2.5
Zone 9 – Room 17	Occupied	Heated only	12	12	n.r.	n.r
Zone 10 – Room 48	Not occupied	n.r.	12	12	2	n.r

2.3.3 Occupancy, lighting, equipment and operating patterns

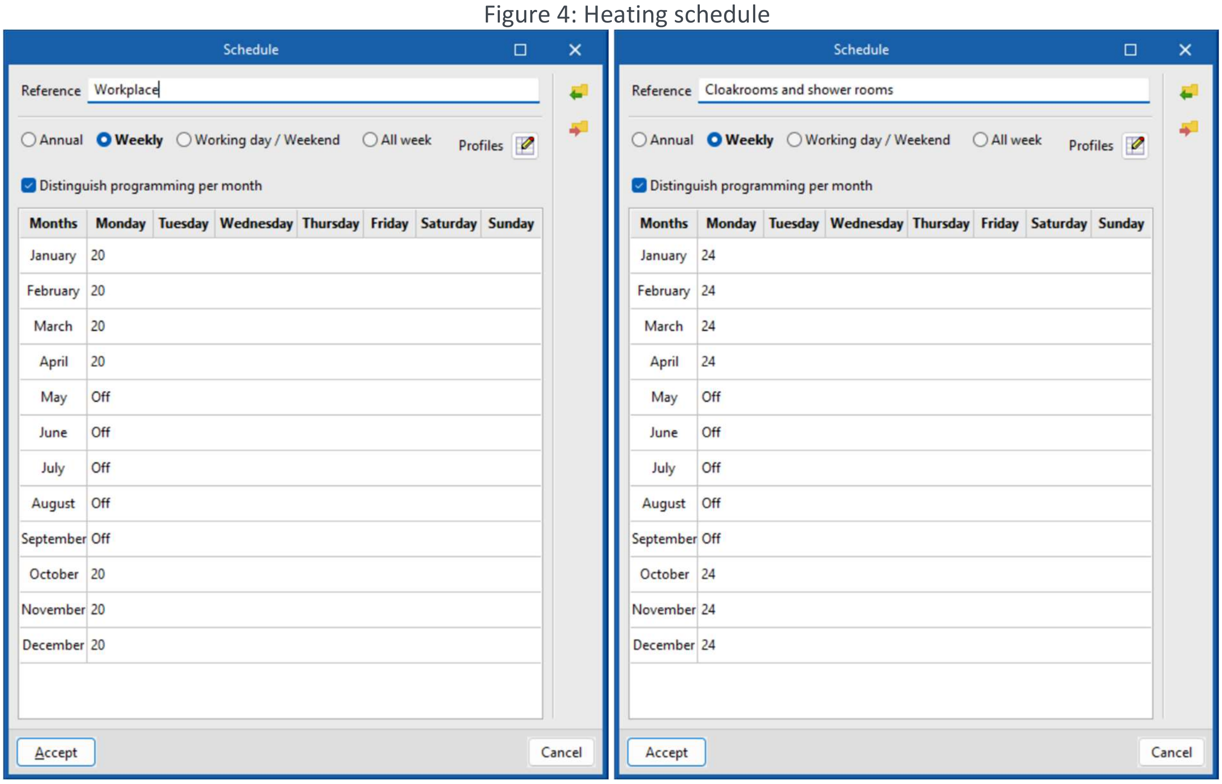
Table 6: Occupancy, lighting, equipment

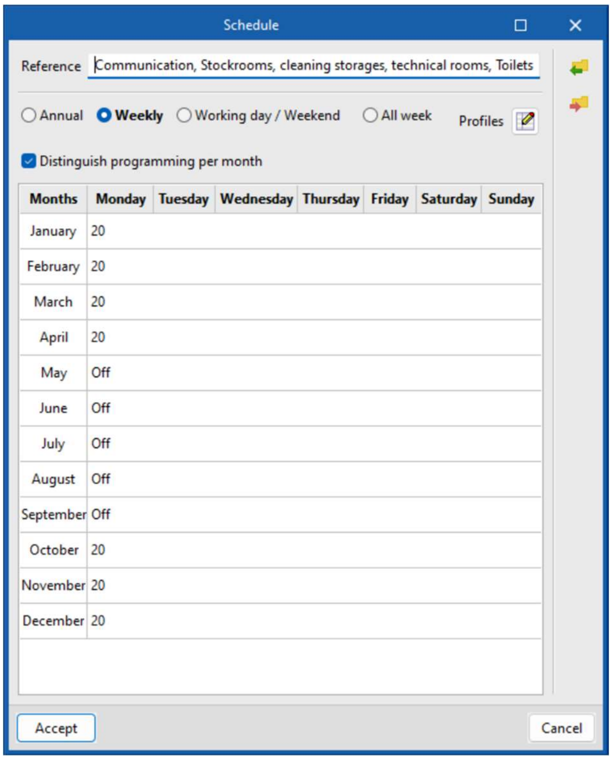
OCCUPIED Space type	LIGHTING Installed power [W] or [W/mq]	EQUIPMENT Installed power [W] or [W/mq]	PEOPLE [m2/person] or [person]	ACTIVITY level [W/person]
Data accuracy	**±1 Wor ± 0,1 W/mq**	**±1 Wor ± 0,1 W/mq**	**±1 person or± mq/person**	**± 1 W/person**
Workplace	7,8 W/mq	100W/mq	3,3 mq/person	126
Cloakrooms	3,7W/mq	279W/mq	2 mq/person	126

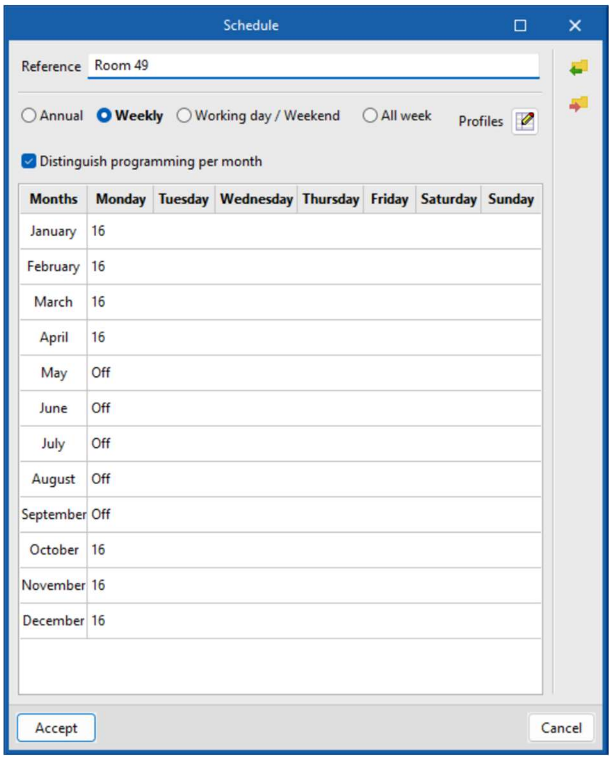
Toilets and shower rooms	5,4W/mq	126W/mq	3,5mq/person	126
Communication	4,6W/mq	13W/mq	114mq/person	126
Waiting room	2,2W/mq	3W/mq	4,5mq/person	100
NOT OCCUPIED - Space type	**LIGHTING Installed power [W] or [W/mq]**	**EQUIPMENT Installed power [W] or [W/mq]**	**NOT OCCUPIED - Space type**	**Air tightness**
Stockrooms	4,1 W/mq	-	-	-
Technical rooms	5,2W/mq	-	-	-
Cleaning storage	4,1 W/mq	-	-	-

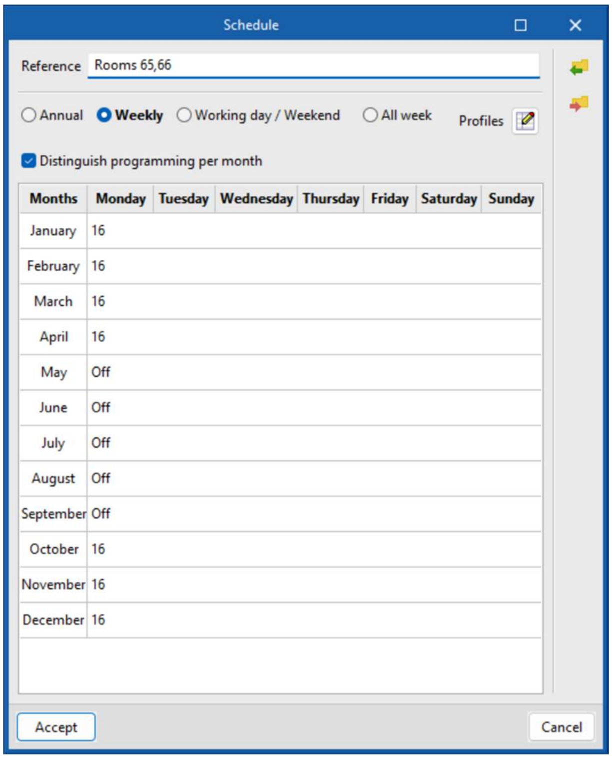
Relevant operating schedules and occupational patterns have been assumed based on standard residential uses and on a few information collected from the users. Following figures show a few of the patterns set for the Warsaw II BEM. Heating patterns for all zones are presented below:

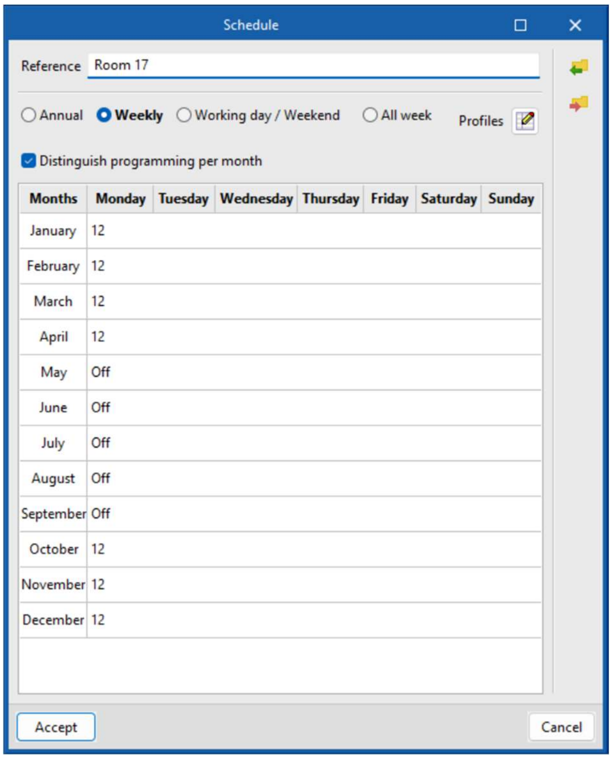
Figure 4: Heating schedule











Cooling patterns are as follows:

Figure 5: Cooling schedule

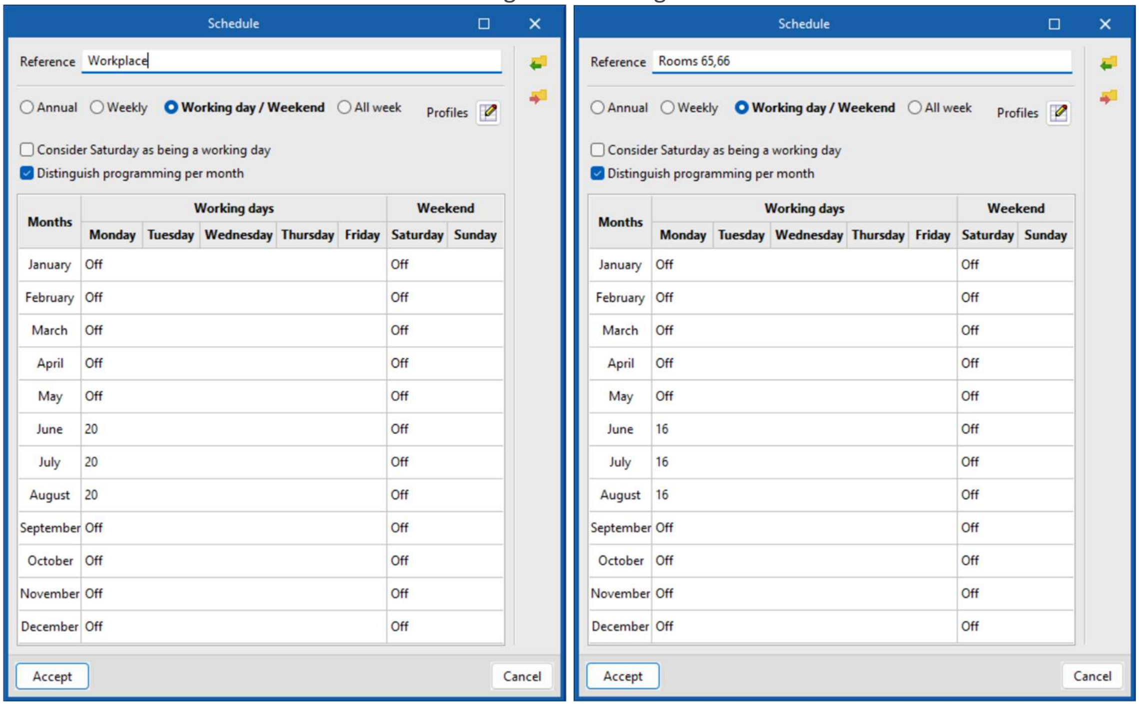
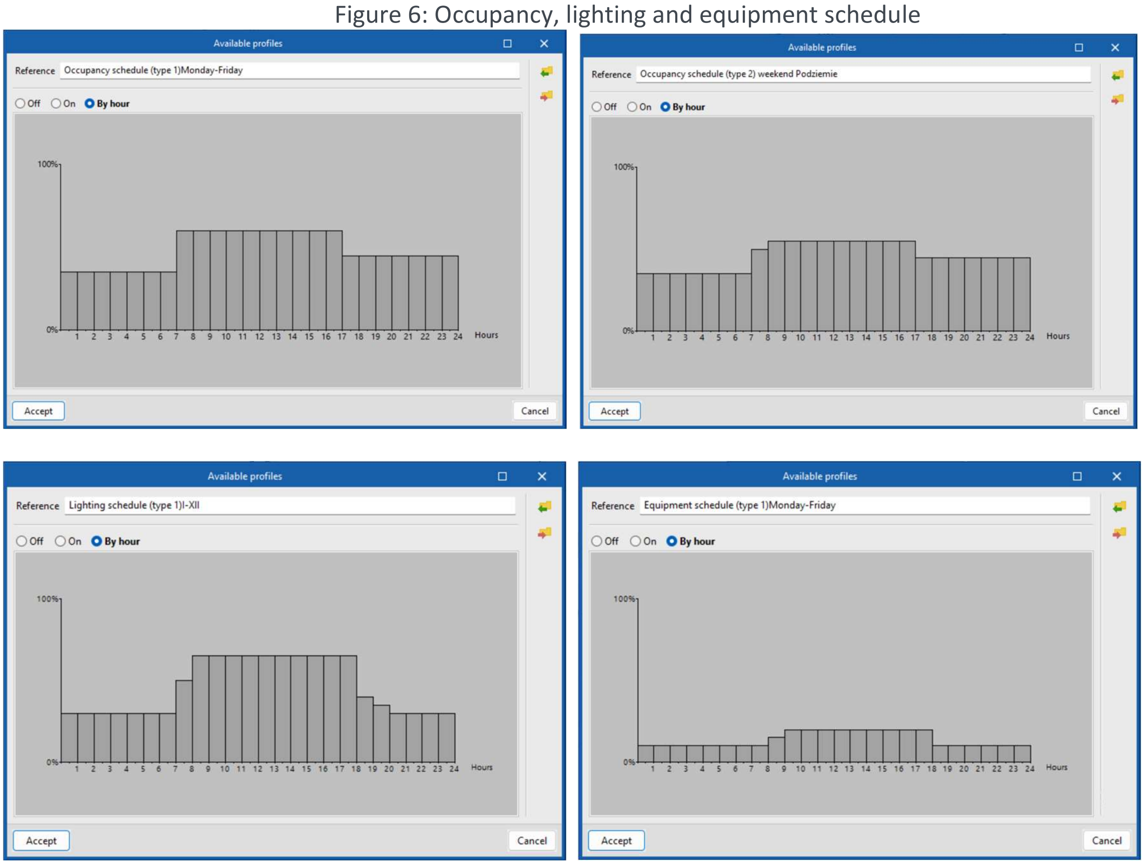


Figure 6: Occupancy, lighting and equipment schedule



3. BEM calibration

The BEM has not been calibrated with the BIM SPEED new procedure (sufficiently detailed data were not available from both the energy bills side and the energy model side).

4. Building energy performance simulation results

4.1 General considerations

For Warsaw II demo, the developed BEM model corresponds to a renovation scenario. No baseline is available and no additional renovation scenarios have been evaluated.

4.2 Energy KPIs

The following Energy KPI have been calculated according to D4.1 descriptions.

BS.OPED: Operational Primary Energy Demand

The primary energy demand has been calculated from the final energy consumption at consumption point and multiplied by the conversion factor (specific for Poland) for final energy to primary energy. The table below summarises the primary energy demand related to natural gas and network electricity.

Table 7: BS.OPED Operational Primary Energy Demand

BS.OPED: Operational Primary Energy Demand	
Ep [kWh/m^2]	284,17

Energy vector	C_{ef} (kWh/year)	C_{ef} (kWh/m ·year)	f_{cep}	C_{ep} (kWh/year)	C_{ep} (kWh/m ·year)
Electricity obtained from the network	26730.07	32.05	2.368	63296.81	75.90
Coal	160216.82	192.13	1.084	173675.03	208.27

C_{ef}: Energy consumption at consumption point (final energy), kWh/m²·year.
f_{cep}: Conversion factor for final energy to primary energy.
C_{ep}: Primary energy consumption, kWh/m²·year.

BS.TED: Total Energy Demand

The energy demand of the building is the total amount of energy the technical systems of the building (heating and cooling) have to provide to maintain its indoor environment in comfortable conditions. The table below summarises the results obtained from the calculation of the heating energy demand.

Table 8: BS.TED Total Energy Demand

BS.TED: Total Energy Demand	
$Q_{HEATING}$ [kWh/m^{2}year]	263,3
$Q_{COOLING}$ [kWh/m^{2}year]	5,4
Q_{DHW} [kWh/m^{2}year]	2,0
Q_{TOT} [kWh/m^{2}year]	**270,7**

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m ·year)
BUILDING (S_c = 833.91 m ; V = 2501.74 m)															
Energy demand	**Heating**	**41828.4**	**39796.8**	**32184.6**	**19911.9**	--	--	--	--	--	**18546.0**	**28400.5**	**38920.3**	**219588.4**	**263.3**
	Cooling	--	--	--	--	--	**1146.2**	**1672.4**	**1672.6**	--	--	--	--	**4491.2**	**5.4**
	DHW	**142.1**	**128.4**	**142.1**	**137.5**	**142.1**	**137.5**	**142.1**	**142.1**	**137.5**	**142.1**	**137.5**	**142.1**	**1673.4**	**2.0**
	TOTAL	**41970.5**	**39925.2**	**32326.7**	**20049.4**	**142.1**	**1283.7**	**1814.5**	**1814.7**	**137.5**	**18688.1**	**28538.0**	**39062.4**	**225753.0**	**270.7**

BS.TEC: Total Energy Consumption

Total Energy Consumption has been calculated directly using the simulation engine of CYPETHERM EPlus. Following table summarises Primary energy consumption for heating and domestic hot water production.

Table 9: BS.TEC Total Energy Consumption

BS.TEC: Total Energy Consumption	
EP_{heat}[kWh/m²]	215.3
EP_{cool}[kWh/m²]	7.5
EP_{light}[kWh/m²]	61.4
EP_{dhw}[kWh/m²]	0
EP_{TOT}[kWh/m²]	**284.2**

		Jan (kWh)	Feb (kWh)	Mar (kWh)	Apr (kWh)	May (kWh)	Jun (kWh)	Jul (kWh)	Aug (kWh)	Sep (kWh)	Oct (kWh)	Nov (kWh)	Dec (kWh)	Year (kWh/year)	Year (kWh/m ·year)
BUILDING (S_c = 833.91 m ; V = 2501.74 m)															
Energy demand	**Heating**	**41828.4**	**39796.8**	**32184.6**	**19911.9**	--	--	--	--	--	**18546.0**	**28400.5**	**38920.3**	**219588.4**	**263.3**
	Cooling	--	--	--	--	--	**1146.2**	**1672.4**	**1672.6**	--	--	--	--	**4491.2**	**5.4**
	DHW	**142.1**	**128.4**	**142.1**	**137.5**	**142.1**	**137.5**	**142.1**	**142.1**	**137.5**	**142.1**	**137.5**	**142.1**	**1673.4**	**2.0**
	TOTAL	**41970.5**	**39925.2**	**32326.7**	**20049.4**	**142.1**	**1283.7**	**1814.5**	**1814.7**	**137.5**	**18688.1**	**28538.0**	**39062.4**	**225753.0**	**270.7**
Electricity (f_{ep} = 1.954)	EF_{heat}	974.8	949.0	27.1	0.8	--	--	--	--	--	0.4	34.0	465.1	2451.2	2.9
	EP_{heat}	2308.3	2247.1	64.2	1.8	--	--	--	--	--	1.0	80.6	1101.3	5804.4	7.0
	$EP_{nr,heat}$	**1904.8**	**1854.3**	**53.0**	**1.5**	--	--	--	--	--	**0.8**	**66.5**	**908.8**	**4789.8**	**5.7**
	EF_{cool}	7.2	7.2	4.9	1.4	--	663.3	978.1	967.9	--	0.8	3.9	7.0	2641.7	3.2
	EP_{cool}	17.1	17.0	11.6	3.2	--	1570.6	2316.1	2292.1	--	1.8	9.2	16.6	6255.5	7.5
	$EP_{nr,cool}$	**14.1**	**14.1**	**9.6**	**2.7**	--	**1296.1**	**1911.3**	**1891.4**	--	**1.5**	**7.6**	**13.7**	**5162.0**	**6.2**
	EF_{dhw}	--	--	--	--	--	--	--	--	--	--	--	--	--	
	EP_{dhw}	--	--	--	--	--	--	--	--	--	--	--	--	--	
	$EP_{nr,dhw}$	--	--	--	--	--	--	--	--	--	--	--	--	--	
	EF_{light}	1837.7	1659.8	1837.7	1778.4	1837.7	1778.4	1837.7	1837.7	1778.4	1837.7	1778.4	1837.7	21637.2	25.9
	EP_{light}	4351.6	3930.5	4351.6	4211.3	4351.6	4211.3	4351.6	4351.6	4211.3	4351.6	4211.3	4351.6	51236.9	61.4
	$EP_{nr,light}$	**3591.0**	**3243.5**	**3591.0**	**3475.1**	**3591.0**	**3475.1**	**3591.0**	**3591.0**	**3475.1**	**3591.0**	**3475.1**	**3591.0**	**42280.7**	**50.7**
Coal (f_{ep} = 1.082)	EF_{heat}	26342.5	24621.6	24288.0	19177.5	--	--	--	--	--	18252.5	22003.7	25531.0	160216.8	192.1
	EP_{heat}	28555.3	26689.8	26328.2	20788.4	--	--	--	--	--	19785.8	23852.1	27675.6	173675.0	208.3
	$EP_{nr,heat}$	**28501.0**	**26639.1**	**26278.1**	**20748.9**	--	--	--	--	--	**19748.2**	**23806.7**	**27623.0**	**173345.0**	**207.9**
	EF_{cool}	--	--	--	--	--	--	--	--	--	--	--	--	--	
	EP_{cool}	--	--	--	--	--	--	--	--	--	--	--	--	--	
	$EP_{nr,cool}$	--	--	--	--	--	--	--	--	--	--	--	--	--	
	EF_{dhw}	--	--	--	--	--	--	--	--	--	--	--	--	--	
	EP_{dhw}	--	--	--	--	--	--	--	--	--	--	--	--	--	
	$EP_{nr,dhw}$	--	--	--	--	--	--	--	--	--	--	--	--	--	
Auto-consumed electricity (f_{ep} = 1.954)	EF	--	--	--	--	--	--	--	--	--	--	--	--	--	
	EP	--	--	--	--	--	--	--	--	--	--	--	--	--	
	EP_{nr}	--	--	--	--	--	--	--	--	--	--	--	--	--	
	$C_{ef,total}$	**29162.2**	**27237.6**	**26157.7**	**20958.1**	**1837.7**	**2441.7**	**2815.8**	**2805.6**	**1778.4**	**20091.4**	**23820.1**	**27840.8**	**186946.9**	**224.2**
	C_{ep}	**35232.3**	**32884.5**	**30755.6**	**25004.7**	**4351.6**	**5781.9**	**6667.7**	**6643.7**	**4211.3**	**24140.2**	**28153.1**	**33145.2**	**236971.8**	**284.2**
	$C_{ep,nr}$	**34010.9**	**31750.9**	**29931.6**	**24228.2**	**3591.0**	**4771.2**	**5502.2**	**5482.4**	**3475.1**	**23341.4**	**27356.0**	**32136.5**	**225577.6**	**270.5**

5. Time reduction evaluation

Following table shows the results of the time reduction for the Warsaw II democase. The BIM SPEED process completed as previously described has been compared to the creation of a BEM using a traditional process, based on the expertise of the Mostostal's energy modeler on similar buildings.

Table 10: Time reduction analysis for the BIM-to-BEM process compared to traditional BEM creation process

	Workflow required for the BEM creation	Traditional process		BIM SPEED PROCESS	
		activity description	time required (working days)	activity description	time required (working days)
1	**BUILDING DATA COLLECTION (site inspection, document/drawing analysis,..), specific data for the thermal characterization are needed**				
	a) direct geometrical measurements (needed if detailed and reliable technical drawings are not available)		2,5	Information extracted directly from BIM	0,25
	b) collection and detection of the thermal characteristics of building components (mapping of windows type, wall type…)		1,5	Information extracted/partially extracted from BIM	1
	c) collection and identification of relevant HVAC characteristics (installed power, type of terminals, …)		0,75	Not included in BIM (same for traditional process)	0,75
	d) data on building operational uses		0,75	Not included in BIM (same for traditional process)	0,75
2	**Building geometry creation**				
	a) 2D floorplans reconstruction from on site measurements (needed if detailed and reliable technical drawings are not available)		2	Not needed - geometrical information extracted directly from BIM	0
	b) creation of the 3D geometry of the building directly with specific Building Energy Simulation tools		5	creation of the Analytical model using BIM (just minor adjustments may be needed)	2,5
3	**Building thermal characterisation**				
	a) creation of the building components and related libraries (e.g. materials, stratigraphies..)		2	the same as traditional process	2
	b) definition of the thermal zones (uses, internal gains - occupancy, lighting, equipment schedules - temperatures..)		2	the same as traditional process	2
4	**HVAC characterisation**				
	a) creation of the HVAC components (and related libraries)		0,75	the same as traditional process	0,75
	b) definition of the systems		1,25	the same as traditional process	1,25
	TOTAL TIME REQUIRED		**18,5**		**11,25**
BIM-to-BEM time reduction compared to current practice: 39%					