Security level: RINA/CL/SENSITIVE

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

Deliverable 4.2 – Energy Performance Report – Gdynia demo

Deliverable Report: Final version, issue date on 31.10.2022

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 - GDYNIA

Deliverable 4.2 – Energy Performance Report

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1. General information

1.1 Building description

The building subjected to the renovation was constructed in year 1961 and it is located in Gdynia (Poland) at street Ruchu Oporu 18. It is a typical residential two-family building. For the retrofitting was subjected left part of the building (single family use), the building is shown in Figure 1 and Figure 2.

Figure 1: Residential building located in Ruchu Oporu 18, Gdańsk, Poland (photo from the Google map)

The building is a three/two storey building, depending on the building side. The level of the terrain is higher on the south part of the building

Figure 2: Photos of the building before the renovation

Table 1: Summary of general data

General information	
Location	Gdynia, Poland
Use category	Single family household
Building type	Two storey building
Construction year	1961
Renovation year	To be renovated
Number of floors	2
Number of apartments/units	2

1.2 GIS and environmental data

In order to apply proper environmental conditions to BEM, Energy+ weather file for nearest available location was included, which is POL_Gdansk.Port.Polnocny.121400_IMGW.epw. Air temperature plot in °C along the year for used weather file is visible in **Error! Reference source not found.**. **Error! Reference source not found.** contains summary of general environmental data.

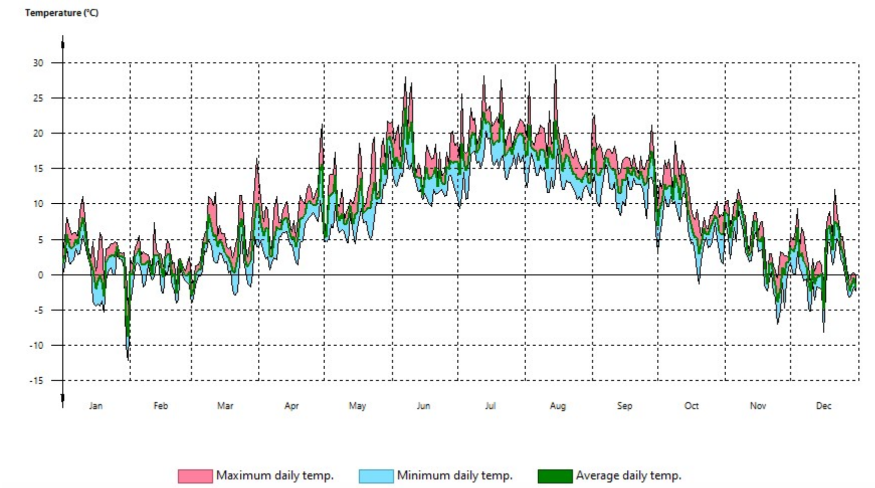


Figure 3: Minimum, maximum and average air temperature distribution

The following table provides a brief summary of the climate data.

Table 2: Summary of general environmental data

General environmental data	
Location	Gdynia, Poland
Weather file	POL_Gdansk.Port.Polnocny.121400_IMGW.epw
Altitude [m]	64
Latitude [degrees]	54
Longitude [degrees]	18
Undistributed temp. of the soil [°C]	10
Network water temperature [°C]	8

2. Energy modelling

2.1 BIM-to-BEM procedure and software tools used

BIM model was exported from Revit into .ifc file. Following the BimSpeed guidelines, next step was upload of .ifc file to bimserver.center platform using Ifc Uploader, provided by CYPE. When the model was on server, another tool Open BIM Analytical Model was used to start operations on previously uploaded BIM model. Main purpose of this software is to generate analytical model from geometry located in .ifc file, but its capabilities is quite wide. In Gdynia demo it was needed to slightly simplify geometry of main entrance of the building. Moreover, there was necessity to define adjacencies of surfaces which are not in contact with surrounding air, such as walls shared with building next to our subject. One of the building's external wall was in contact with soil, which was also possible to apply with used tool. Last step in Open BIM Analytical Model is to create thermal spaces and assign them into groups differentiating by the room purpose and usage profile.

Ready and saved analytical model is uploaded once again into bimserver.center platform and ready to import into Open BIM Construction Systems tool. Software was used to define 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 definition of BEM model. All thermal boundary conditions are applied here to the model such as rooms temperature profiles, lighting, ventilation, occupancy and so on.

2.2 Auditing procedures and data collection

Draft Building Information Model for the building was available before the project has started. The gathering of the data was performed through the on-site visit and discussion with the building owner.

2.3 Description of BEM's technical features

Looking from the front of the building, there are three stores and two entrances on first and second level. On the back side, lowest level's wall is under the ground, so there was a need to define it as basement wall. Walls adjacent to another building were assumed as adiabatic, as there was no documented knowledge about thermal properties of sibling construction.

2.3.1 Envelope components and materials

Envelope and internal partitions data were collected from buildings documentation, confronted by on-site assessment and aggregated into Energy data collection spreadsheet. Gathering partitions data needed for BEM creation made the process faster and more reliable. Table contains materials used in the model.

Table 3: Materials

Layers					
Material	e	ρ	λ	RT	Cp
Plaster_03	3.00	1120.00	0.059	0.51	0.96
Polystyrene_12	12.00	1050.00	1.500	0.08	1.30
Brick, Common_38	38.00	1550.00	0.704	0.54	0.84
Plaster_02	2.00	1120.00	0.039	0.51	0.96
Polystyrene_06	6.00	1050.00	0.750	0.08	0.13
Polystyrene_10	10.00	1050.00	1.250	0.08	0.13
Brick, Common_48	48.00	1550.00	0.889	0.54	0.84
Plaster_01,5	1.50	1120.00	0.029	0.51	0.96
Brick, Common_24	24.00	1550.00	0.444	0.54	0.84
Plaster_01	1.00	1120.00	0.020	0.51	0.96
Brick, Common_10	10.00	1550.00	0.185	0.54	0.84
Roofing, EPDM Membrane	1.00	930.00	0.072	0.14	2.09
Concrete, Sand/cement screed	10.00	950.00	0.478	0.21	0.66
Concrete masonry unit _27	27.00	1800.00	0.208	1.30	0.84
Cement_03	30.00	1860.00	0.417	0.72	0.84
Concrete, Lightweight_06	6.00	950.00	0.287	0.21	0.66
Brick, Common_16	16.00	1550.00	0.296	0.54	0.84
Cement_03	30.00	1860.00	0.417	0.72	840.00
Concrete, Lightweight_06	6.00	950.00	0.287	0.21	657.00
Concrete masonry unit _22	22.00	1800.00	0.169	1.30	840.00
Plaster_01	1.00	1120.00	0.020	0.51	960.00
Concrete, Lightweight_06	6.00	950.00	0.478	0.13	0.66
Concrete masonry unit _22	22.00	1800.00	0.169	1.30	0.84
Cement_02	20.00	1860.00	0.278	0.72	0.84
Concrete, Lightweight_10	10.00	950.00	0.478	0.21	0.66
Gravel	15.00	1840.00	0.625	0.24	0.84

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

Within following tables all the construction systems created for the Gdynia 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]**	**Total Thickness [cm]**
Data accuracy	**every material present**	**± 1 cm**	**± 1 cm**
Exterior brick wall - 270mm	Plaster_01,5	1,5	27
	Brick, Common_24	24	
	Plaster_01,5	1,5	
Exterior brick wall - 560mm	Plaster_03	3	56
	Polystyrene_12	12	
	Brick, Common_38	38	

	Plaster_03	3	
Exterior brick wall - 200mm	Plaster_01	1	20
	Brick, Common_18	18	
	Plaster_01	1	
Exterior brick wall - 640mm	Plaster_03	3	64
	Polystyrene_10	10	
	Brick, Common_48	48	
	Plaster_03	3	
Internal Walls_Reference name	**Layers**	**Thickness [cm]**	**Total Thickness [cm]**
Data accuracy	**every material present**	**± 1 cm**	**± 1 cm**
Interior brick wall - 120mm	Plaster_01	1	12
	Brick, Common_10	10	
	Plaster_01	1	
Interior brick wall - 400mm	Plaster_01	1	40
	Brick, Common_38	38	
	Plaster_01	1	
Interior brick wall - 270mm	Plaster_01,5	1,5	27
	Brick, Common_24	24	
	Plaster_01,5	1,5	
Interior brick wall - 200mm	Plaster_01	1	20
	Brick, Common_18	18	
	Plaster_01	1	
Underground Walls_Reference name	**Layers**	**Thickness [cm]**	**Total Thickness [cm]**
Data accuracy	**every material present**	**± 1 cm**	**± 1 cm**
Exterior brick wall - 480mm	Plaster_02	2	48
	Polystyrene_06	6	
	Brick, Common_38	38	
	Plaster_02	2	
Slab on Grounf Floor_Reference name	**Layers**	**Thickness [cm]**	**Total Thickness [cm]**
Data accuracy	**every material present**	**± 1 cm**	**± 1 cm**
Bacement floor	Cement_02	2	30,00
	Cement_03	3	
	Concrete, Lightweight	10	
	Gravel	15	
Floor Slabs_Reference name	**Layers**	**Thickness [cm]**	**Total Thickness [cm]**
Data accuracy	**every material present**	**± 1 cm**	**± 1 cm**
Floor 0	Cement_03	3	32,00
	Concrete, Lightweight_06	6	
	Concrete, Masonry units_22	22	
	Plaster_01	1	
Floor 1	Cement_03	3	26,00
	Concrete, Lightweight_06	6	
	Brick, Common_16	16	
	Plaster_01	1	
Roofs_Reference name	**Layers**	**Thickness [cm]**	**Total Thickness [cm]**
Data accuracy	**every material present**	**± 1 cm**	**± 1 cm**
Flat Roof	Roofing, EPDM Membrane	1	40,00

	Concrete, Sand/cement screed	10	
	Roofing, EPDM Membrane	1	
	Concrete, Masonry units_27	27	
	Plaster_01	1,00	

Table 5: Construction systems

Reference name	Thermal transmittance WINDOW [W/m2K]
Data accuracy	± 0,01
Windows_Sgl_Plain	3,1292
Windows_Dbl_Plain	3,1292
M_single-flush_int_80x200	3,18
M_single-flush_ext_84x200	2,61

2.3.2 HVAC systems

In simulated building, there are three types of thermal zones: three types of heated, occupied zones and other is not occupied nor heated.

Table 6: HVAC systems

Thermal zone	Space classification	Min comfort temperature [°C]	Ventialation demand	DHW demand [l/day]
Data accuracy	n.r. (description)	± 1 °C	± 1 l/s	± 1 l/day
Thermal Zone 01	Occupied	20	8,3	35 per person
Thermal Zone 02	Occupied	24	13,9	35 per person
Thermal Zone 03	Occupied	17	8.3	35 per person
Thermal Zone 04	Not occupied	n.r.	n.r.	n.r.

Following figures show the HVAC setting of each thermal zone.

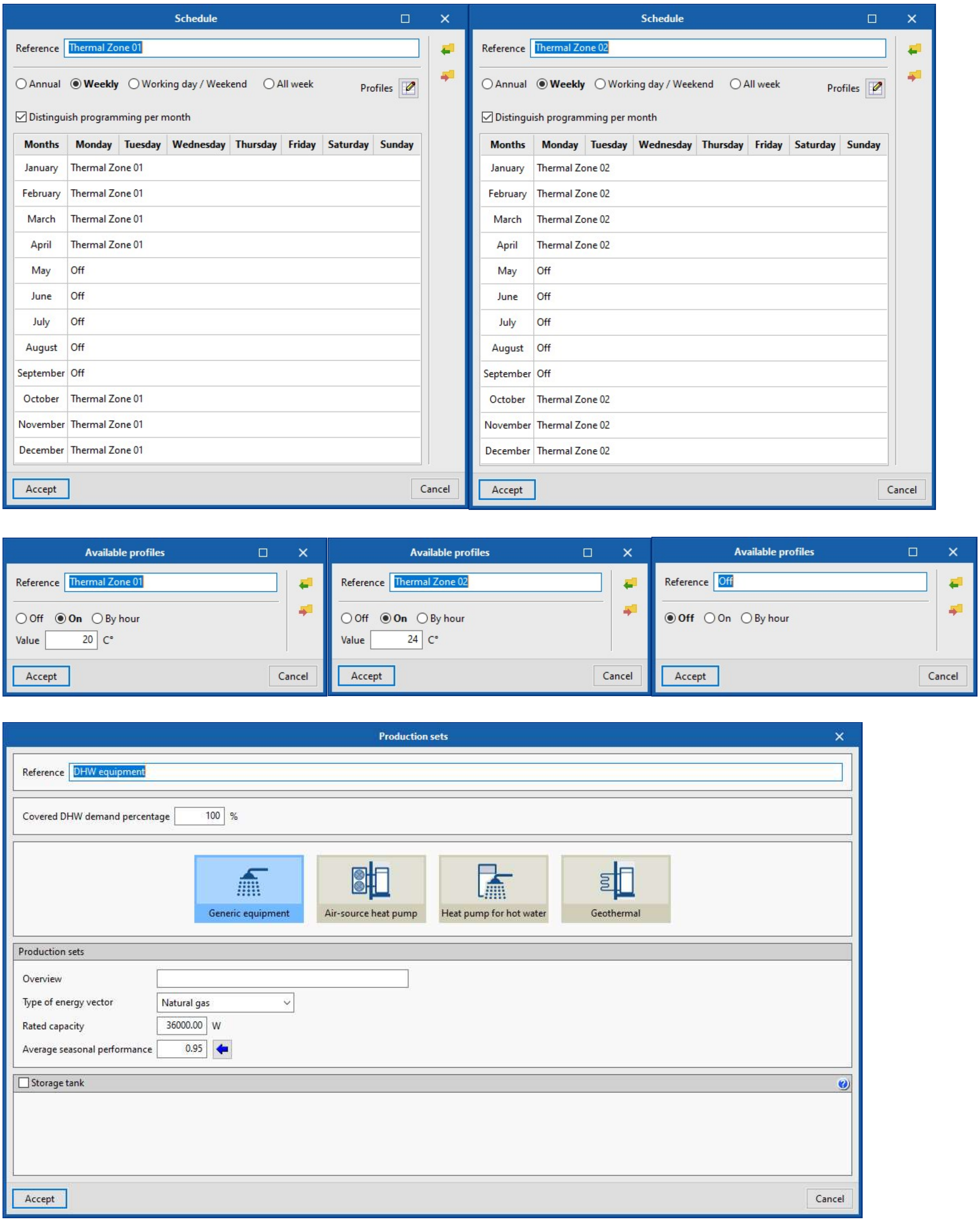


Figure 4: HVAC settigns

2.3.3 Occupancy, lighting, equipment and operating patterns

Gdynia BEM has been characterised also under the point of view of the internal gains as summarised in following table 7.

Table 7: Internal gains features

Thermal zone	Space classification	Installed light power [W/m2]	Internal equipment [W/m2]	Occupancy activity level [W/person]
Thermal Zone 01	Occupied	1,9	8,3	126
Thermal Zone 02	Occupied	9,5	13,9	-
Thermal Zone 03	Occupied	1.9	8.3	126
Thermal Zone 04	Not occupied	-	-	-

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 Gdynia BEM.

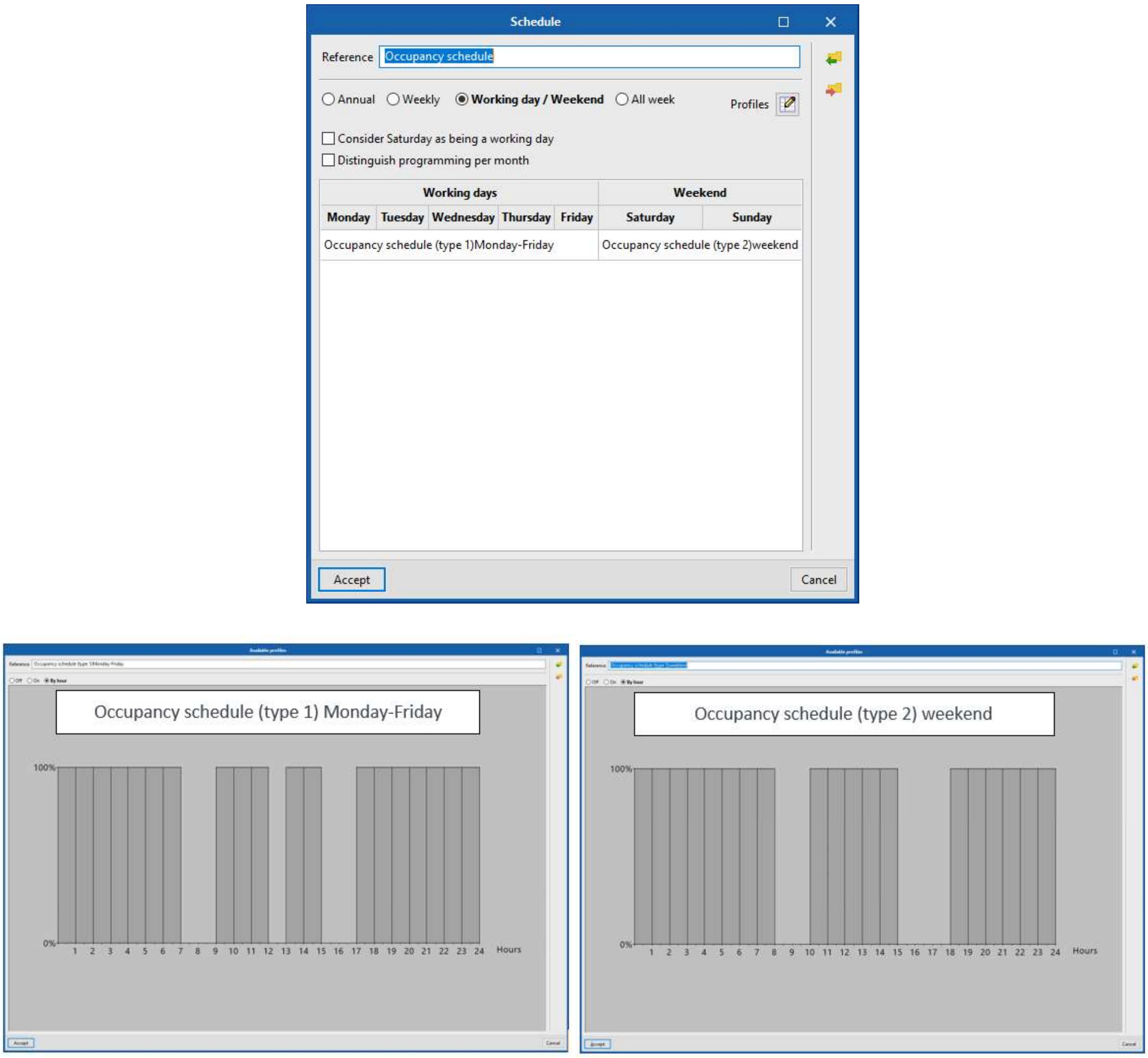


Figure 5: Occupancy schedule

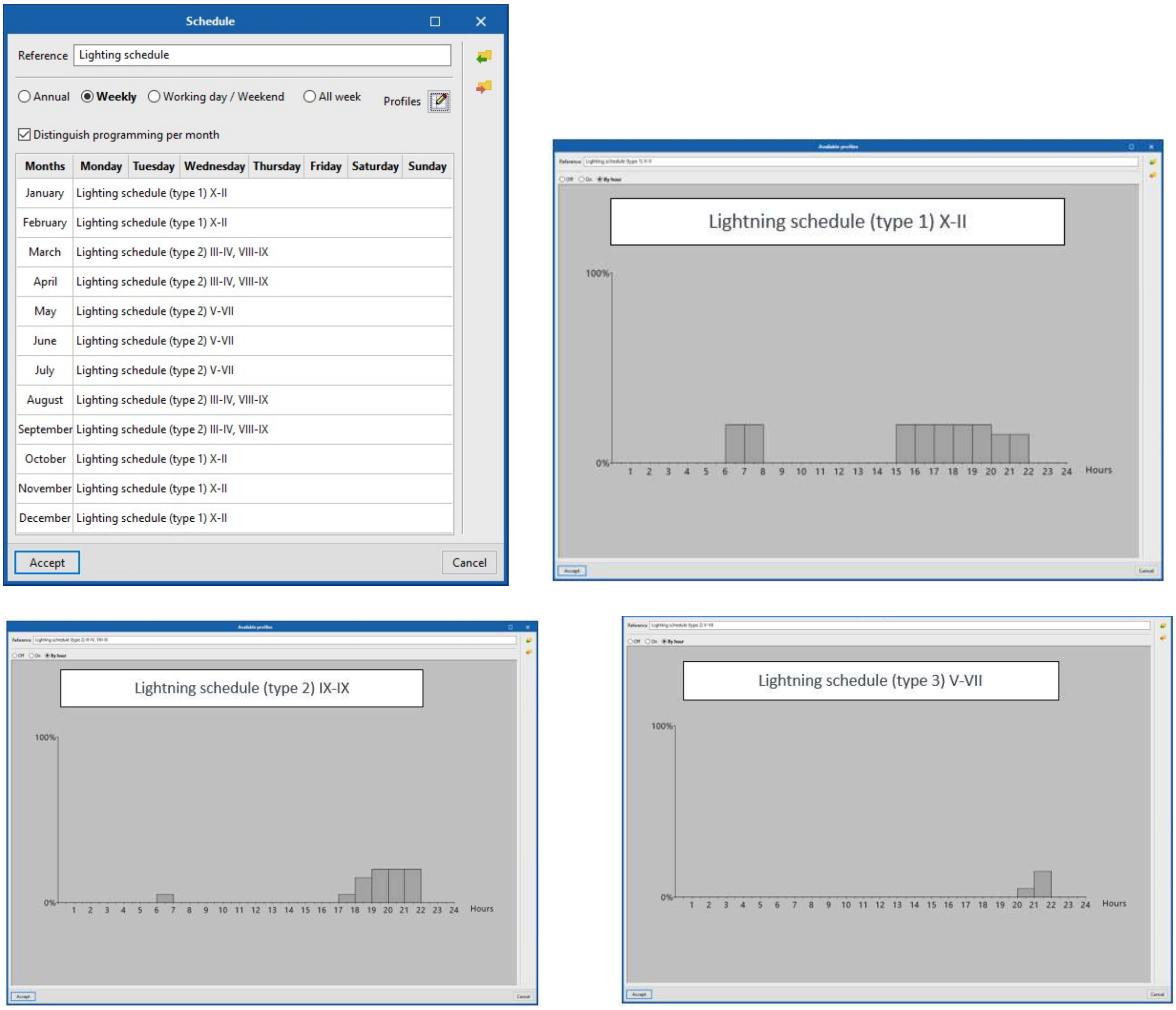
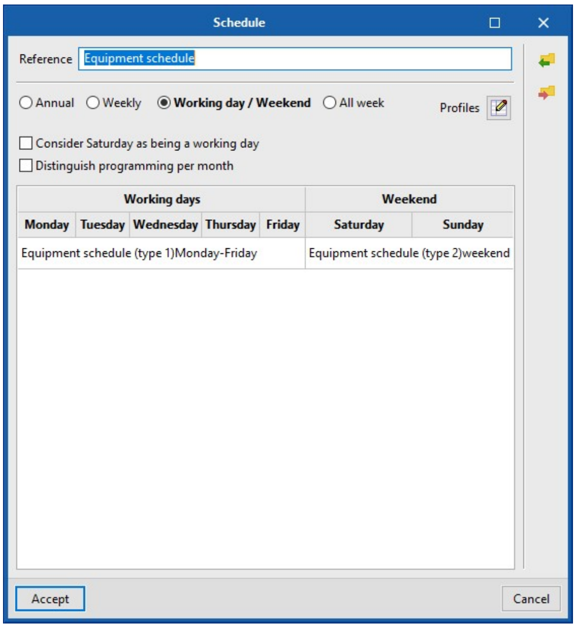


Figure 6: Lighting schedule



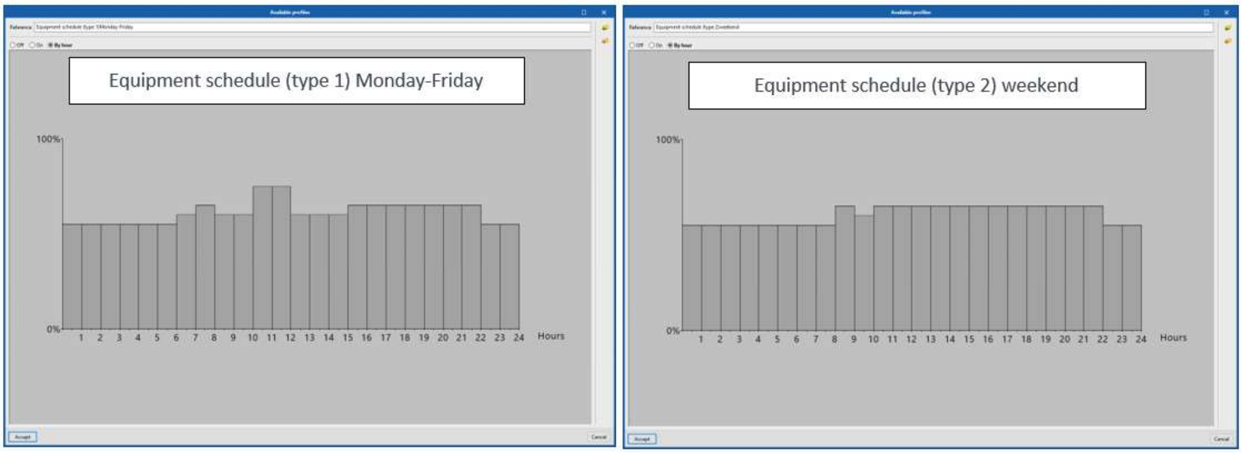


Figure 7: Equipment schedule

3. BEM calibration

3.1 Calibration methodology applied and results

Owner of simulated building was not able to provide annual thermal energy utilization data. Due to the fact that calibration methodology and energy calculations with the use of CypeTherm+ were performed within P2ENDURE research project (https://www.p2endure-project.eu/en), and the demonstration building in Gdynia (from BIM-SPEED project) and demonsrration buildings from P2ENDURE project have been constructed with similar consyruction technology, the calibration approach from P2ENDURE project was reapeated for Gdynia demonstration project. In P2Endure project in Polish demonstration buildings (in Gdynia and Warsaw) were successfully calibrated basing on real annual thermal energy utilization data. Because of many similarities of both buildings, we decided to repeat calibration steps from P2Endure building energy model in current BEM case. Calibration methodology basically assumes that ventilation performance is decreased by 15% in all building's thermal spaces.

4. Building energy performance simulation results

4.1 General considerations

All openings of the simulated building have very poor thermal insulation properties with factors 3.3 W/m2K for windows and 2.6 W/m2k for entrance doors.

Most of external walls are insulated with 12 cm of polystyrene. Only external walls of entrance halls are not insulated al all, while underground walls from the back side of the building have 6cm layer of polystyrene.

The highest heat consumption exists in thermal zones with highest minimum air temperature and ventilation requirements, such as bathrooms and kitchen. In simulated building two of three bathrooms happen to be located on the lowest, underground level with walls adjacent to the soil. As mentioned before, these walls are insulated only with 6cm of polystyrene.

Analysis of results shows that the most heat consuming per square meter are entrance halls and underground bathrooms. However, due to poor thermal performance of all window openings also all other spaces characterize with high energy consumption.

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 8: BS.OPED Operational Primary Energy Demand

BS.OPED: Operational Primary Energy Demand	
Ep [kWh/m^2]	34.60

Energy vector	$C_{ef,total}$ (kWh/year)	(kWh/m²·year)	f_{cep}	$C_{ep,nr}$ (kWh/year)	(kWh/m²·year)
Natural gas	4261.62	29.10	1.189	5067.17	34.60

where:

$C_{ef,total}$: *Total energy consumption at consumption point, kWh/m²·year.*

f_{cep}: *Conversion factor for final energy to primary energy obtained from non-renewable sources.*

$C_{ep,nr}$: *Total non-renewable 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 (there is no cooling for the Gdynia demo)

Table 9: BS.TED Total Energy Demand

BS.TED: Total Energy Demand	
$Q_{HEATING}$ [kWh/m^{2}year]	152.6
Q_{DHW} [kWh/m^{2}year]	27.6
Q_{TOT} [kWh/m^{2}year]	**180.3**

		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/m²·year)
BUILDING (S_u = 146.44 m²; V = 412.82 m³)															
Energy demand	**Heating**	**3844.0**	**3743.9**	**3392.6**	**2011.2**	--	--	--	--	--	**2025.6**	**3335.5**	**3998.9**	**22351.6**	**152.6**
	DHW	**343.8**	**310.6**	**343.8**	**332.8**	**343.8**	**332.8**	**343.8**	**343.8**	**332.8**	**343.8**	**332.8**	**343.8**	**4048.5**	**27.6**
	TOTAL	**4187.8**	**4054.5**	**3736.4**	**2343.9**	**343.8**	**332.8**	**343.8**	**343.8**	**332.8**	**2369.4**	**3668.3**	**4342.7**	**26400.2**	**180.3**

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.

		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/m²·year)
BUILDING (S_u = 146.44 m²; V = 412.82 m³)															
Energy demand	**Heating**	**3844.0**	**3743.9**	**3392.6**	**2011.2**	--	--	--	--	--	**2025.6**	**3335.5**	**3998.9**	**22351.6**	**152.6**
	DHW	**343.8**	**310.6**	**343.8**	**332.8**	**343.8**	**332.8**	**343.8**	**343.8**	**332.8**	**343.8**	**332.8**	**343.8**	**4048.5**	**27.6**
	TOTAL	**4187.8**	**4054.5**	**3736.4**	**2343.9**	**343.8**	**332.8**	**343.8**	**343.8**	**332.8**	**2369.4**	**3668.3**	**4342.7**	**26400.2**	**180.3**
Natural gas (f_{cep} = 1.189)	EF_{heat}	4046.3	3941.0	3571.1	2117.0	--	--	--	--	--	2132.9	3511.1	4209.3	23528.7	160.7
	EP_{heat}	4835.3	4709.5	4267.5	2529.8	--	--	--	--	--	2548.8	4195.7	5030.1	28116.8	192.0
	$EP_{nr,heat}$	**4811.1**	**4685.9**	**4246.2**	**2517.2**	--	--	--	--	--	**2536.1**	**4174.8**	**5005.0**	**27976.2**	**191.0**
	EF_{cool}	--	--	--	--	--	--	--	--	--	--	--	--	--	
	EP_{cool}	--	--	--	--	--	--	--	--	--	--	--	--	--	
	$EP_{nr,cool}$	--	--	--	--	--	--	--	--	--	--	--	--	--	
	EF_{dhw}	361.9	326.9	361.9	350.3	361.9	350.3	361.9	361.9	350.3	361.9	350.3	361.9	4261.6	29.1
	EP_{dhw}	432.5	390.7	432.5	418.6	432.5	418.6	432.5	432.5	418.6	432.5	418.6	432.5	5092.6	34.8
	$EP_{nr,dhw}$	**430.4**	**388.7**	**430.4**	**416.5**	**430.4**	**416.5**	**430.4**	**430.4**	**416.5**	**430.4**	**416.5**	**430.4**	**5067.2**	**34.6**
Auto-consumed electricity (f_{cep} = 1.954)	EF	--	--	--	--	--	--	--	--	--	--	--	--	--	
	EP	--	--	--	--	--	--	--	--	--	--	--	--	--	
	EP_{nr}	--	--	--	--	--	--	--	--	--	--	--	--	--	
	$C_{ef,total}$	**4408.2**	**4267.9**	**3933.1**	**2467.3**	**361.9**	**350.3**	**361.9**	**361.9**	**350.3**	**2494.9**	**3861.3**	**4571.3**	**27790.3**	**189.8**
	C_{ep}	**5267.8**	**5100.2**	**4700.0**	**2948.4**	**432.5**	**418.6**	**432.5**	**432.5**	**418.6**	**2981.4**	**4614.3**	**5462.7**	**33209.5**	**226.8**
	$C_{ep,nr}$	**5241.5**	**5074.7**	**4676.5**	**2933.6**	**430.4**	**416.5**	**430.4**	**430.4**	**416.5**	**2966.4**	**4591.2**	**5435.4**	**33043.4**	**225.6**

where:

- S_u: *Residential area of the building, m².*
- V: *Net residential area of the building, m³.*
- f_{cep}: *Conversion factor for final energy to primary energy obtained from non-renewable sources.*
- EF: *Final energy consumed by the system at consumption point, kWh.*
- EP: *Primary energy consumption, kWh.*
- EP_{nr}: *Non-renewable primary energy consumption, kWh.*
- $C_{ef,total}$: *Total energy consumption at consumption point, kWh/m²·year.*
- C_{ep}: *Total primary energy consumption, kWh/m²·year.*
- $C_{ep,nr}$: *Total non-renewable primary energy consumption, kWh/m²·year.*

Table 10: BS.TEC Total Energy Consumption

BS.TEC: Total Energy Consumption	
EP_{heat}[kWh/m²]	192.0
EP_{cool}[kWh/m²]	Cooling not present
EP_{light}[kWh/m²]	7
EP_{dhw}[kWh/m²]	34.8
EP_{TOT}[kWh/m²]	**233.8**

5. Building renovation scenarios

There were several improvements proposed to baseline state of building. As a result, four renovation scenarios were defined. Each of them consists of certain enhancements to envelope or building systems. All of them are listed and described below.

5.1 Renovation scenarios proposed

For the Gdynia democase, the following building renovation scenarios have been assessed according to Task 7.1 premises. The following table summarises the configuration of each scenario.

Table 11: Overview of the Gdynia Renovation Scenarios - Envelope

	Building Envelope					
	1. External Wall insulation	2. Ventilated	3. Rooftop module	4. Windows	5. Second window	6. Indoor insulation (floors)
Scenario 01	x	-	x	x	x	x
Scenario 02	-	x	-	-	x	x
Scenario 03	x	-	x	x	-	x
Scenario 03	x	-	x	x	-	x

Table 12: Overview of the Gdynia Renovation Scenarios – Building Systems

	Building Systems						
	7. Lighting	8. Radiators	9. Piping	10. Boilers	11. Ventilation	12. PV	13. Thermal solar
Scenario 01	x	x	x	x	-	-	x
Scenario 02	x	x	-	-	x	-	-
Scenario 03	x	-	-	-	-	-	-
Scenario 03	x	-	-	-	-	x	-

1. ETICS – External wall insulation

External walls and basement's wall are insulated as following:

Position:	*External walls*					
Product website	https://lambda.swisspor.pl/pl/page/29/lambda-plus-fasada					
EXT	*Thermal Conductivity (W/mK)*	*thickness (m)*	*Thermal Transmittance U (W/m^2K)*	*Thermal resistance R (W/m^2K)*	*Total thickness (m)*	*Total Thermal Transmittance U (W/m^2K)*
EPS 032	0.032	0.12	0.26	3.75	**0.68**	**0.225**
Brick wall	0.80	0.56	1.43	0.70		
		0.52	1.54	0.65	**0.64**	**0.227**
		0.40	2.00	0.50	**0.52**	**0.235**
		0.27	2.96	0.34	**0.39**	**0.244**
INT						

Position:	*External bacement walls*					
Product website	https://termoorganika.pl/plyty-z-polistyrenu-ekstrudowanego-xps?gclid=CjC					
EXT	*Thermal Conductivity (W/mK)*	*thickness (m)*	*Thermal Transmittance U (W/m^{2}K)*	*Thermal resistance R (W/m^{2}K)*	*Total thickness (m)*	*Total Thermal Transmittance U (W/m^{2}K)*
Styrodur XPS 200-036	0.036	0.12	0.30	3.33	**0.50**	**0.263**
Brick wall	0.80	0.38	0.48	0.48		
		0.27	0.34	0.34	**0.39**	**0.273**
INT						

2. Ventilated

External walls are insulated and also ventilated as following

Position:	*External walls*					
duct website						
EXT	*Thermal Conductivity (W/mK)*	*thickness (m)*	*Thermal Transmittance U (W/m^{2}K)*	*Thermal resistance R (W/m^{2}K)*	*Total thickness (m)*	*Total Thermal Transmittance U (W/m^{2}K)*
Facing	*0.23*	*0.08*	*0.285*	*0.35*	*0.79*	*0.176*
Air gap	*0.025*	*0.03*	*0.83*	*1.2*		
EPS 032	0.032	0.12	0.29	3.43		
Brick wall	0.80	0.56	1.43	0.70		
		0.52	1.54	0.65	**0.75**	**0.178**
		0.40	2.00	0.50	**0.67**	**0.183**
		0.27	2.96	0.34	**0.54**	**0.188**
INT						

3. Rooftop module

Flat roof is insulated with EPS

Position:	*Flat roof*					
Product website	https://lambda.swisspor.pl/pl/page/29/lambda-plus-fasada					
EXT	*Thermal Conductivity (W/mK)*	*thickness (m)*	*Thermal Transmittance U (W/m^{2}K)*	*Thermal resistance R (W/m^{2}K)*	*Total thickness (m)*	*Total Thermal Transmittance U (W/m^{2}K)*
Bitumen membrane	0.180	0.01	18.00	0.06	**0.50**	**0.227**
EPS 032	0.032	0.20	0.29	3.43		
Bitumen membrane	0.180	0.01	18.00	0.06		
DMS ceilling	1.080	0.27	4.00	0.25		
Plaster	0.80	0.01	1.64	0.61		
INT						

4. Windows

Windows are replaced and installed with insulation break between them and building façade insulation.

Manufactor	DRUTEX			
Product ID	IGLO Energy Classic			
hermal Transmittance	0.9	W/m^2K		
Product website	https://www.drutex.pl/pl/produkty/iglo-energy-classic.html			

5. Secondary windows

Same windows as above, but installed without thermal bridge between them and façade insulation.

6. Indoor insulation (floors)

Interior and basement floors are insulated.

Position:	*Bacement floor*					
Product website	https://termoorganika.pl/gold-dach-podloga					
INT	*Thermal Conductivity (W/mK)*	*thickness (m)*	*Thermal Transmittance U (W/m^2K)*	*Thermal resistance R (W/m^2K)*	*Total thickness (m)*	*Total Thermal Transmittance U (W/m^2K)*
Terracotta	1.050	0.02	52.50	0.02		
Concrete	1.050	0.08	13.13	0.08		
EPS 036	0.036	0.10	0.36	0.56	**0.41**	**0.360**
Bitumen felt	0.180	0.01	18.00	0.06		
Concrete	0.600	0.10	6.00	0.17		
Gravel	0.900	0.10	9.00	0.11		
EXT						

Position:	*Interior floor I*					
Product website	https://termoorganika.pl/gold-dach-podloga					
INT	*Thermal Conductivity (W/mK)*	*thickness (m)*	*Thermal Transmittance U (W/m^2K)*	*Thermal resistance R (W/m^2K)*	*Total thickness (m)*	*Total Thermal Transmittance U (W/m^2K)*
Oak flooring	0.220	0.02	1.10	0.91		
Concrete	1.050	0.06	17.50	0.06		
EPS 100	0.036	0.04	0.90	1.11	**0.35**	**0.710**
Concrete blocks slab	0.250	0.22	1.14	0.88		
Plaster	0.700	0.01	70.00	0.01		
INT						

Position:	*Interior floor II*					
Product website	https://termoorganika.pl/gold-dach-podloga					
INT	*Thermal Conductivity (W/mK)*	*thickness (m)*	*Thermal Transmittance U (W/m^2K)*	*Thermal resistance R (W/m^2K)*	*Total thickness (m)*	*Total Thermal Transmittance U (W/m^2K)*
Oak flooring	0.220	0.02	1.10	0.91		
Concrete	1.050	0.06	17.50	0.06		
EPS 100	0.036	0.04	0.90	1.11	**0.35**	**0.550**
Klein's ceilling	0.700	0.22	3.18	0.31		
Plaster	0.700	0.01	70.00	0.01		
INT						

7. Lightening

Light bulbs are replaced with LEDs decreasing electricity consumption.

OCCUPIED Space type	LIGHTING Installed power [W] or [W/mq]
Rooms	0,7W/mq
Kitchen/Bathrooms	0,9W/mq

8. Radiators

Radiators are replaced with newer steel panel heaters.

9. Piping

Central heating piping is replaced and insulated, increasing overall system efficiency.

10. Boiler

Boiler is replaced with energy efficient gas condensing boiler.

Manufactor	VIESSMANN	
Product ID	Vitodens 100-W	
Nominal Power	32	kW
Product website	https://www.viessmann.pl/pl/budynki-mieszkalne/kotly-gazowe/gazowe-kotly-kondensacyjne/vitodens-100-w-vitodens-111-w.html	

11. 11. Ventilation

All ventilation ducts are replaced which ensure proper air flow through the system.

12. 12. PV

Assumed 5000 kWh/year is produced from PV installation located on the roof of the building.

13. 13 Thermal Solar

Domestic hot water is heated up with solar collectors, which lowers environmental fingerprint and primal energy demand.

5.2 Scenario 1: description and results

Scenario 1 consists of:

- ETICS
- Rooftop module
- Windows
- Indoor insulation (floors)
- Radiators
- Piping
- Boilers
- Thermal Solar

The following KPIs have been calculated:

BS.OPED: Operational Primary Energy Demand

Table 13: BS.OPED Operational Primary Energy Demand

BS.OPED: Operational Primary Energy Demand	
Ep [kWh/m^2]	105.17

Energy vector	C_{ef} (kWh/year)	C_{ef} (kWh/m²·year)	$f_{cep,nr}$	$C_{ep,nr}$ (kWh/year)	$C_{ep,nr}$ (kWh/m²·year)
Natural gas	12886.43	88.00	1.189	15322.29	104.63
Electricity obtained from the network	40.55	0.28	1.954	79.24	0.54

$C_{ef,total}$: Total energy consumption at consumption point, kWh/m²·year.
$f_{cep,nr}$: Conversion factor for final energy to primary energy obtained from non-renewable sources.
$C_{ep,nr}$: Total non-renewable primary energy consumption, kWh/m²·year.

BS.TED: Total Energy Demand

Table 14: BS.TED Total Energy Demand

BS.TED: Total Energy Demand	
$Q_{HEATING}$ [kWh/m^{2}year]	96.4
Q_{DHW} [kWh/m^{2}year]	27.7
Q_{TOT} [kWh/m^{2}year]	**124.1**

BS.TEC: Total Energy Consumption (and sub KPIs; Energy consumption for heating, cooling, lighting, DHW)

Table 15: BS.TEC Total Energy Consumption

BS.TEC: Total Energy Consumption	
EP_{heat}[kWh/m^2]	105.2
EP_{cool}[kWh/m^2]	Cooling not present
EP_{light}[kWh/m^2]	0.7
EP_{dhw}[kWh/m^2]	34.8
EP_{TOT}[kWh/m^2]	**105.9**

BS.TES: Total Energy savings

Table 16: BS.TES Total Energy Savings

BS.TES: Total Energy Savings			
	Baseline	Scenario 01	SAVING
EP_{heat}[kWh/m^2]	192	105.2	86.8
EP_{cool}[kWh/m^2]	Cooling not present		
EP_{light}[kWh/m^2]	7	0.7	6.3
EP_{dhw}[kWh/m^2]	34.8	34.8	-
EP_{TOT}[kWh/m^2]	**233.8**	**140.7**	**93.1**

5.3 Scenario 2: description and results

Scenario 2 consists of:

- Ventilated
- Second window

- Indoor insulation (floors)
- Lighting
- Radiators
- Ventilation

The following KPIs have been calculated:

BS.OPED: Operational Primary Energy Demand

Table 17: BS.OPED Operational Primary Energy Demand

BS.OPED: Operational Primary Energy Demand	
Ep [kWh/m^2]	140.15

Energy vector	C_{ef} (kWh/year)	C_{ef} (kWh/m²·year)	$f_{cep,nr}$	$C_{ep,nr}$ (kWh/year)	$C_{ep,nr}$ (kWh/m²·year)
Natural gas	17195.14	117.42	1.189	20445.45	139.61
Electricity obtained from the network	40.55	0.28	1.954	79.24	0.54

where:

$C_{ef,total}$: Total energy consumption at consumption point, kWh/m²·year.
$f_{cep,nr}$: Conversion factor for final energy to primary energy obtained from non-renewable sources.
$C_{ep,nr}$: Total non-renewable primary energy consumption, kWh/m²·year.

BS.TED: Total Energy Demand

Table 18: BS.TED Total Energy Demand

BS.TED: Total Energy Demand	
$Q_{HEATING}$ [kWh/m^{2}year]	128.9
Q_{DHW} [kWh/m^{2}year]	27.7
Q_{TOT} [kWh/m^{2}year]	**156.6**

BS.TEC: Total Energy Consumption (and sub KPIs; Energy consumption for heating, cooling, lighting, DHW)

Table 19: BS.TEC Total Energy Consumption

BS.TEC: Total Energy Consumption	
EP_{heat}[kWh/m^2]	140.3
EP_{cool}[kWh/m^2]	Cooling not present
EP_{light}[kWh/m^2]	0.7
EP_{dhw}[kWh/m^2]	34.8
EP_{TOT}[kWh/m^2]	**175.8**

BS.TES: Total Energy savings

Table 20: BS.TES Total Energy Savings

BS.TES: Total Energy Savings	Baseline	Scenario 02	SAVING
EP_{heat}[kWh/m^2]	192	140.3	51.7
EP_{cool}[kWh/m^2]	Cooling not present		
EP_{light}[kWh/m^2]	7	0.7	6.3
EP_{dhw}[kWh/m^2]	34.8	34.8	-
EP_{TOT}[kWh/m^2]	**233.8**	**175.8**	**58**

5.4 Scenario 3: description and results

Scenario 3 consists of:

- ETICS
- Rooftop module
- Windows
- Indoor insulation (floors)
- Lighting

The following KPIs have been calculated:

BS.OPED: Operational Primary Energy Demand

Table 21: BS.OPED Operational Primary Energy Demand

BS.OPED: Operational Primary Energy Demand	
Ep [kWh/m^2]	121.24

Energy vector	C_{ef} (kWh/year)	C_{ef} (kWh/m²·year)	$f_{cep,nr}$	$C_{ep,nr}$ (kWh/year)	$C_{ep,nr}$ (kWh/m²·year)
Natural gas	14865.42	101.51	1.189	17675.36	120.70
Electricity obtained from the network	40.55	0.28	1.954	79.24	0.54

where:

$C_{ef,total}$: Total energy consumption at consumption point, kWh/m²·year.
$f_{cep,nr}$: Conversion factor for final energy to primary energy obtained from non-renewable sources.
$C_{ep,nr}$: Total non-renewable primary energy consumption, kWh/m²·year.

BS.TED: Total Energy Demand

Table 22: BS.TED Total Energy Demand

BS.TED: Total Energy Demand	
$Q_{HEATING}$ [kWh/m^{2}year]	96.4
Q_{DHW} [kWh/m^{2}year]	27.7
Q_{TOT} [kWh/m^{2}year]	**124.1**

BS.TEC: Total Energy Consumption (and sub KPIs; Energy consumption for heating, cooling, lighting, DHW)

Table 23: BS.TEC Total Energy Consumption

BS.TEC: Total Energy Consumption	
EP_{heat}[kWh/m^2]	121.3
EP_{cool}[kWh/m^2]	Cooling not present
EP_{light}[kWh/m^2]	0.7
EP_{dhw}[kWh/m^2]	34.8
EP_{TOT}[kWh/m^2]	**156.8**

BS.TES: Total Energy savings

Table 24: BS.TES Total Energy Savings

BS.TES: Total Energy Savings			
	Baseline	Scenario 03	SAVING
EP_{heat}[kWh/m^2]	192	121.3	70.7
EP_{cool}[kWh/m^2]	Cooling not present		
EP_{light}[kWh/m^2]	7	0.7	6.3

EP_{dhw}[kWh/m²]	34.8	34.8	-
EP_{TOT}[kWh/m²]	**233.8**	**156.8**	**77**

5.5 Scenario 4: description and results

Scenario 4 consists of:

- ETICS
- Rooftop module
- Windows
- Indoor insulation (floors)
- Lighting
- PV

The following KPIs have been calculated:

BS.OPED: Operational Primary Energy Demand

Table 25: BS.OPED Operational Primary Energy Demand

BS.OPED: Operational Primary Energy Demand	
Ep [kWh/m²]	54.52

Energy vector	C_{ef} (kWh/year)	C_{ef} (kWh/m²·year)	$f_{cep,nr}$	$C_{ep,nr}$ (kWh/year)	$C_{ep,nr}$ (kWh/m²·year)
Natural gas	14865.42	101.51	1.189	17675.36	120.70
Electricity obtained from the network	-4959.45	-33.87	1.954	-9691.12	-66.18
Electricity produced on site (renewable)	5000.00	34.14	0.000	--	--

where:

$C_{ef,total}$: Total energy consumption at consumption point, kWh/m²·year.

$f_{cep,nr}$: Conversion factor for final energy to primary energy obtained from non-renewable sources.

$C_{ep,nr}$: Total non-renewable primary energy consumption, kWh/m²·year.

BS.TED: Total Energy Demand

Table 26: BS.TED Total Energy Demand

BS.TED: Total Energy Demand	
$Q_{HEATING}$ [kWh/m²year]	96.4
Q_{DHW} [kWh/m²year]	27.7
Q_{TOT} [kWh/m²year]	**124.1**

BS.TEC: Total Energy Consumption (and sub KPIs; Energy consumption for heating, cooling, lighting, DHW)

Table 27: BS.TEC Total Energy Consumption

BS.TEC: Total Energy Consumption	
EP_{heat}[kWh/m²]	121.3
EP_{cool}[kWh/m²]	Cooling not present
EP_{light}[kWh/m²]	0.7
EP_{dhw}[kWh/m²]	34.8
EP_{PV} [kWh/m²]	-80.9
EP_{TOT}[kWh/m²]	**75.9**

BS.TES: Total Energy saving

Table 28: BS.TES Total Energy Savings

BS.TES: Total Energy Savings			
	Baseline	Scenario 03	SAVING
EP_{heat}[kWh/m²]	192	121.3	70.7
EP_{cool}[kWh/m²]	Cooling not present		
EP_{light}[kWh/m²]	7	0.7	6.3
EP_{dhw}[kWh/m²]	34.8	34.8	-
EP_{PV} [kWh/m²]	0	-80.9	80.9
EP_{TOT}[kWh/m²]	**233.8**	**75.9**	**157.9**

6. Time reduction evaluation

Following table shows the results of the time reduction for the Gdynia 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 FASADA on similar buildings.

Table 29: 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	Information extracted/partially extracted from BIM	0,75
	c) collection and identification of relevant HVAC characteristics (installed power, type of terminals, …)		0,5	Not included in BIM (same for traditional process)	0,5
	d) data on building operational uses		0,5	Not included in BIM (same for traditional process)	0,5
2	**Building geometry creation**				
	a) 2D floorplans reconstruction from on site measurements (needed if detailed and reliable technical drawings are not available)		1,5	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		3	creation of the Analytical model using BIM (just minor adjustments may be needed)	1,25
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)		0,5	the same as traditional process	0,5
	b) definition of the systems		1	the same as traditional process	1
	TOTAL TIME REQUIRED		**14.5**		**8,75**
BIM-to-BEM time reduction compared to current practice: 40%					