Project Documentation
Gebäude-Dokumentation

1 Abstract / Zusammenfassung

Office building in Al Khawaneej, Dubai, UAE

1.1 Data of building / Gebäudedaten

Year of construction/ Baujahr	2016	**Space heating / Heizwärmebedarf**	**0 kWh/(m²a)**
U-value external wall/ U-Wert Außenwand	0.076 W/(m²K) 0.090 W/(m²K)	**Space cooling / Kühlbedarf**	**50 kWh/(m²a)**
U-value basement ceiling/ U-Wert Kellerdecke	0.108 W/(m²K)	**Primary Energy Renewable (PER) / Erneuerbare Primärenergie (PER)**	73 kWh/(m²a)
U-value roof/ U-Wert Dach	0.076 W/(m²K)	**Generation of renewable energy / Erzeugung erneuerb. Energie**	185 kWh/(m²a)
U-value window/ U-Wert Fenster	0.89 W/(m²K)	**Non-renewable Primary Energy (PE) / Nicht erneuerbare Primärenergie (PE)**	143 kWh/(m²a)
Heat recovery/ Wärmerückgewinnung	89 %	Pressure test n_{50} / Drucktest n_{50}	0.48 h^{-1}
Special features/ Besonderheiten	electric storage 25kWh, water recovery from condensation drain		

1.2 Brief Description

Office building in Al Khawaneej, Dubai, UAE

Dubai's government through the Mohammed Bin Rashid Space Centre (MBRSC), took the decision to translate the theoretical feasibility for a Passive House in very hot climate into practice.

The main goal of the project was to verify the effectiveness of PH standard in terms of energy saving and indoor comfort – in view of a wide application in Dubai's real estate market.

The building is composed by two above ground floors, with a usable surface (as per PHPP calculation) of 410 m2 and a S/V ratio of 0,58. The site location is within the city of Dubai, close to the existing MBRSC buildings.

From an architectural point of view, the building stands as a monolith, with its east and west views having almost no openings, a north view characterized by an added external volume serving as vestibule room and a south view that recalls the concept of the inner court, typical of hot climate architectures. Almost all the glazing concentrate in the inner court, that is protected from direct sunlight by means of an external concrete wall and by means of the photovoltaic (PV) field over the flat roof which effectively acts as a shadow in the central hours of the day. This permitted to minimize solar gains and this solar architecture design (or, we could better say, anti-solar design), allowed for low direct radiation loads with at the same time the possibility to use natural diffuse light.

The building is realized with a timber structure, following what is a well known construction technology in central Europe: the platform-frame technology. This choice represents however an unicum in Dubai and at first sight it could be seen as a weirdness, because a lightweight building is not the first thing one think about in a hot climate. Dubai's climate is however different from a typical Mediterranean climate, in which day / night temperature excursion makes it possible to 'passively' exploit load / unload cycles of the internal thermal masses, thus reducing the cooling energy consumption. On the other hand, in Dubai very often external thermo-hygrometrical conditions are unfavourable all day long; in this case internal thermal masses cannot be passively unloaded; on the contrary they need to be actively kept under control in order to avoid surcharges. A lightweight structure is thus not inappropriate.

The mechanical system is obviously focused on cooling. Chilled water is generated by a water / water heat pump, with an external dry cooler. The produced chilled water has a design flow temperature of 7 °C, which guarantees air condensation and thus allows to completely cover latent load (being latent load often the higher portion of the total cooling load). Latent load is treated in air / water coils which are placed in the supply air ducts of the heat recovery ventilation (HRV) units. There are 3, PH certified, HRVs with static sensible heat recovery (latent heat recovery was an option but so far no complete performance data are available for such devices); flow rates have been designed to fulfil PH requirements together with ASHRAE 62.1 requirements. These coils are coupled with a second, hot water operated, coil in case pure dehumidification service is required.

In normal cases, as per PH functional definition, treating the incoming external air allows to satisfy the whole latent load and a huge part of the sensible load. However, being the building used as an office, the internal heat gains are pretty high; to face this problem additional fan coils operating at 7 °C were installed to match the uncovered sensible load.

At last, a radiant floor system was installed with a design flow temperature of 20 °C, which is higher than usual design temperature. In fact, radiant floor is used to keep the screed fresh enough (roughly 23 °C). Radiant floor is thus a way to keep masses under control rather than a real cooling system. Having the floor at a controlled temperature, lower than set temperature, allows for lower mean radiant temperature thus enhancing the thermal comfort.

The electrical system is based on a building automation architecture with HDL protocol. Other than usual building automation functions, some distinctive features have been designed in order to help minimize internal heat gains pertaining to equipment and lighting. In addition to the exclusive use of high efficiency LED lighting, every working room is equipped with a lux meter to adjust the intensity of artificial lighting, based on actual value of natural lighting. Moreover, venetian blinds are automatically operated and are programmed to completely shut down after worktime. In the same way, after worktime the building automation system cuts off the power supply of electronic devices to avoid any stand-by losses.

The building is provided with a PV field composed by polycrystalline silicon modules for a total power of 40 kW, coupled with a 25 kWh electrical storage. The combination of these two systems should allow for energy independency; this design result will be verified with the monitoring.

1.3 Responsible project participants / Verantwortliche Projektbeteiligte

Architect/ Entwurfsverfasser	Casetta&Partners – Giancarlo Casetta – Mauro Bonotto http://www.casettaepartners.it
Implementation planning/ Ausführungsplanung	Wolf Haus / Wolf System http://www.wolfhaus.it
Building systems/ Haustechnik	University of Bergamo - Antonio Perdichizzi – Giuseppe Franchini http://www.unibg.it Energy Plus Project – Michele Dorigo – Marco Filippi – Alessandro Palamidese http://www.enepplus.it
Structural engineering/ Baustatik	Simon Keller / Wolf System (woodworks) Giancarlo Casetta (reinforced concrete works)
Building physics/ Bauphysik	Energy Plus Project –Marco Filippi Casetta&Partners – Mauro Bonotto
Passive House project planning/ Passivhaus-Projektierung	Energy Plus Project –Marco Filippi http://www.enepplus.it
Construction management/ Bauleitung	Wolf Haus / Wolf System http://www.wolfhaus.it
Certifying body/ Zertifizierungsstelle	Herz&Lang www.herz-lang.com
Certification ID/ Zertifizierungs ID	Project-ID 5065
Author of project documentation / Verfasser der Gebäude-Dokumentation	Energy Plus Project –Marco Filippi http://www.enepplus.it
Date, Signature/ Datum, Unterschrift	Pieve di Soligo, 23.02.2017

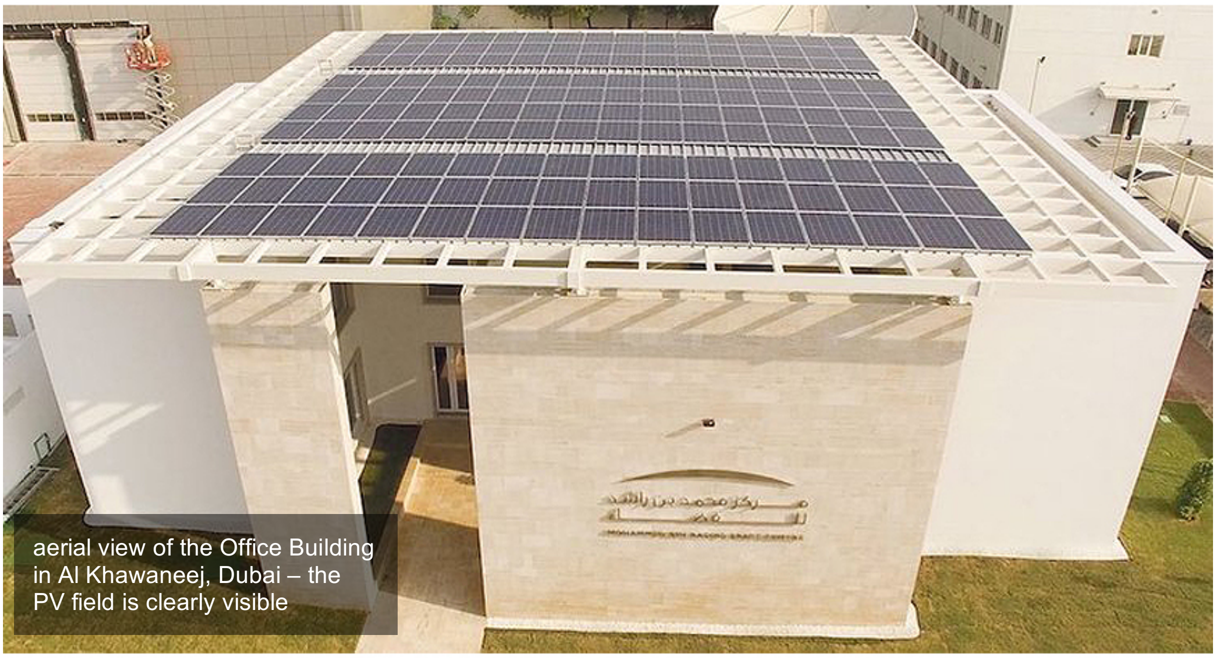
2 Views of the Office Building in Al Khawaneej, Dubai

south/east view of the Office Building in Al Khawaneej, Dubai. The inner court and the shading due to the PV field are visible (Photograph: Mauro Bonotto)

south view of the Office Building in Al Khawaneej, Dubai (Photograph: Mauro Bonotto)

north/west view of the Office
Building in Al Khawaneej, Dubai
(Photograph: Mauro Bonotto)

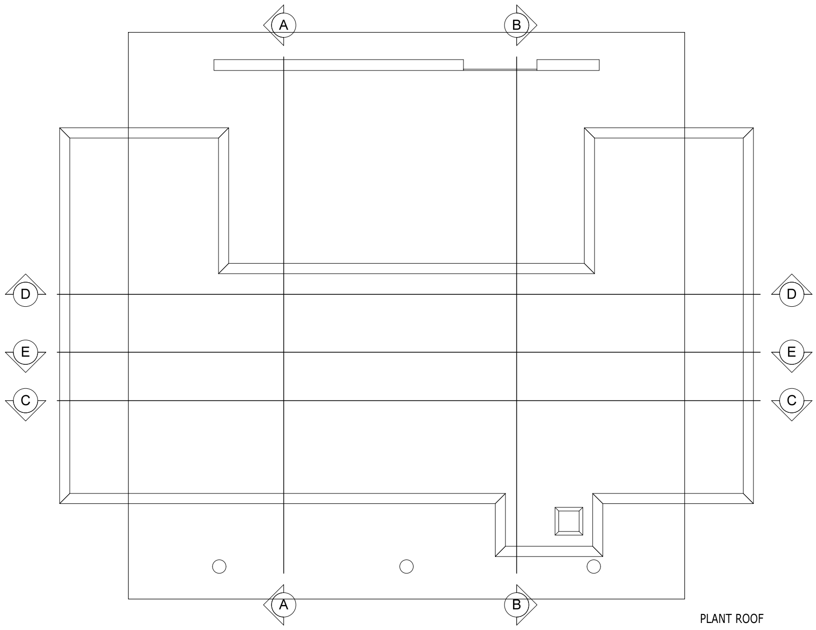
north/east view of the Office
Building in Al Khawaneej, Dubai
(Photograph: Mauro Bonotto)

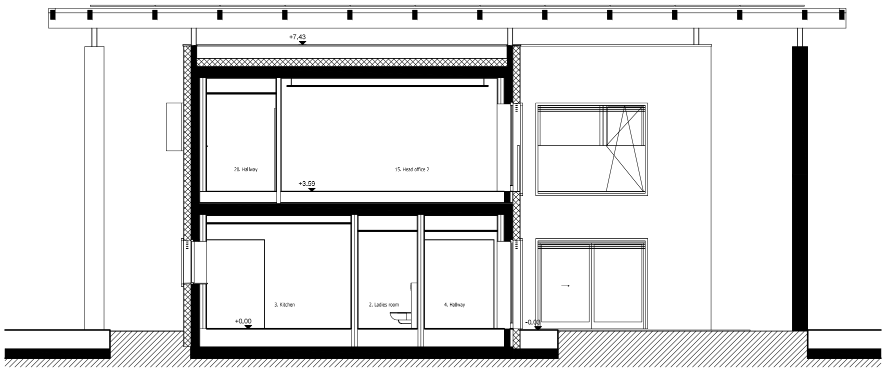


aerial view of the Office Building in Al Khawaneej, Dubai – the PV field is clearly visible

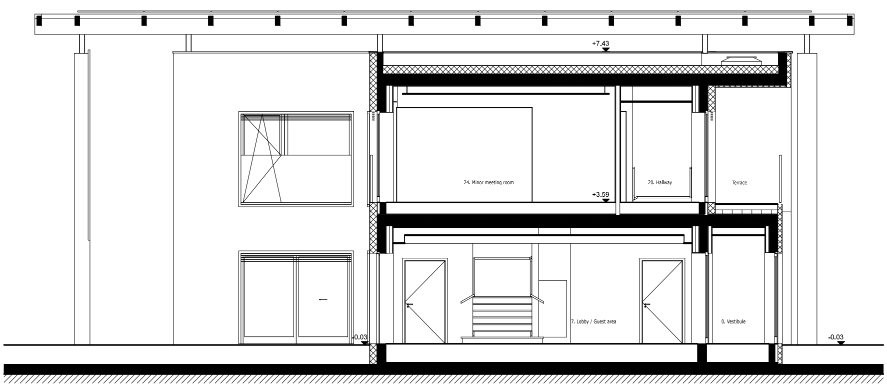
the lobby / pre-meeting room of the Office Building in Al Khawaneej, Dubai

3 Sectional drawings of the Office Building in Al Khawaneej, Dubai

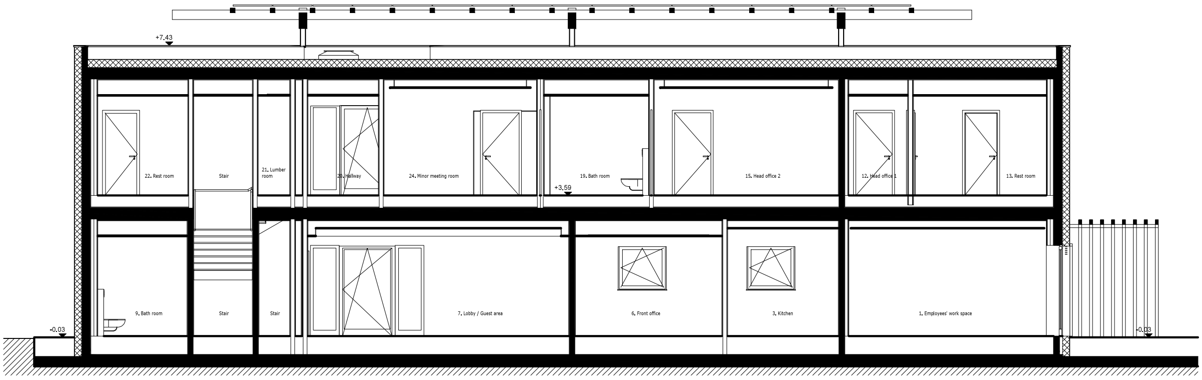




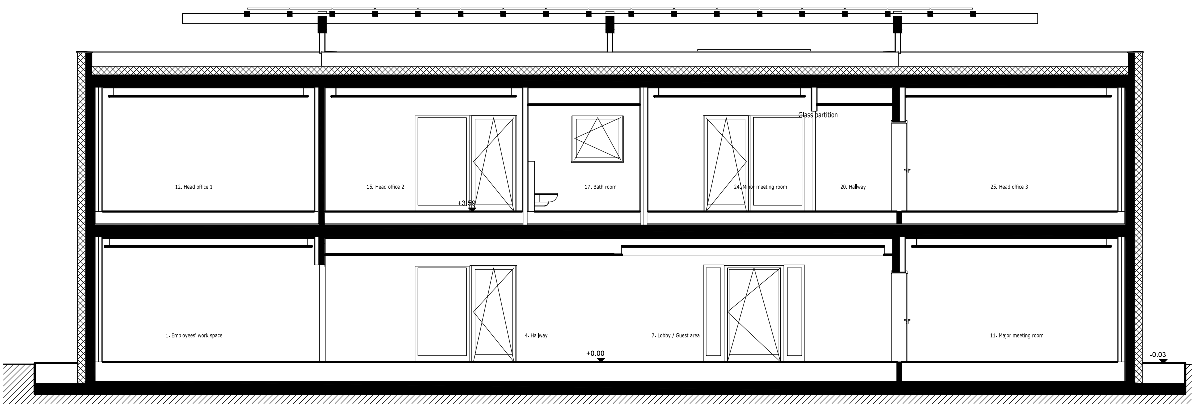
SECTION A-A



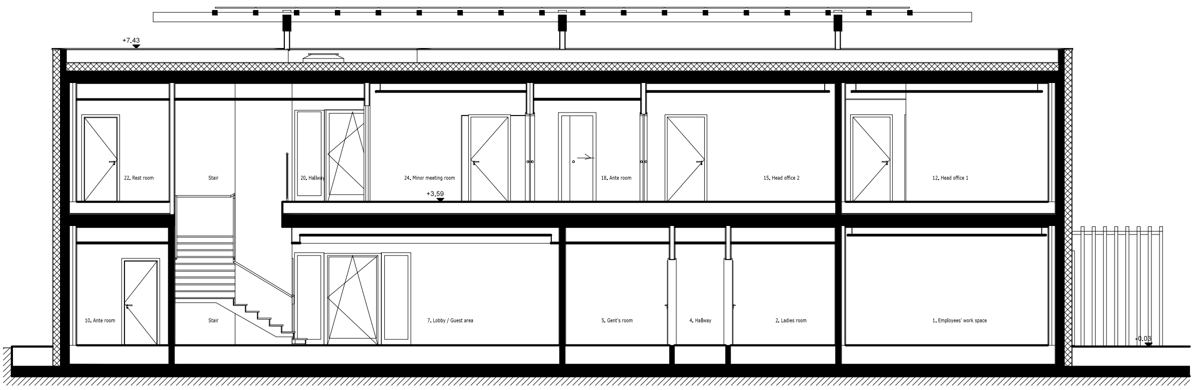
SECTION B-B



SECTION C-C

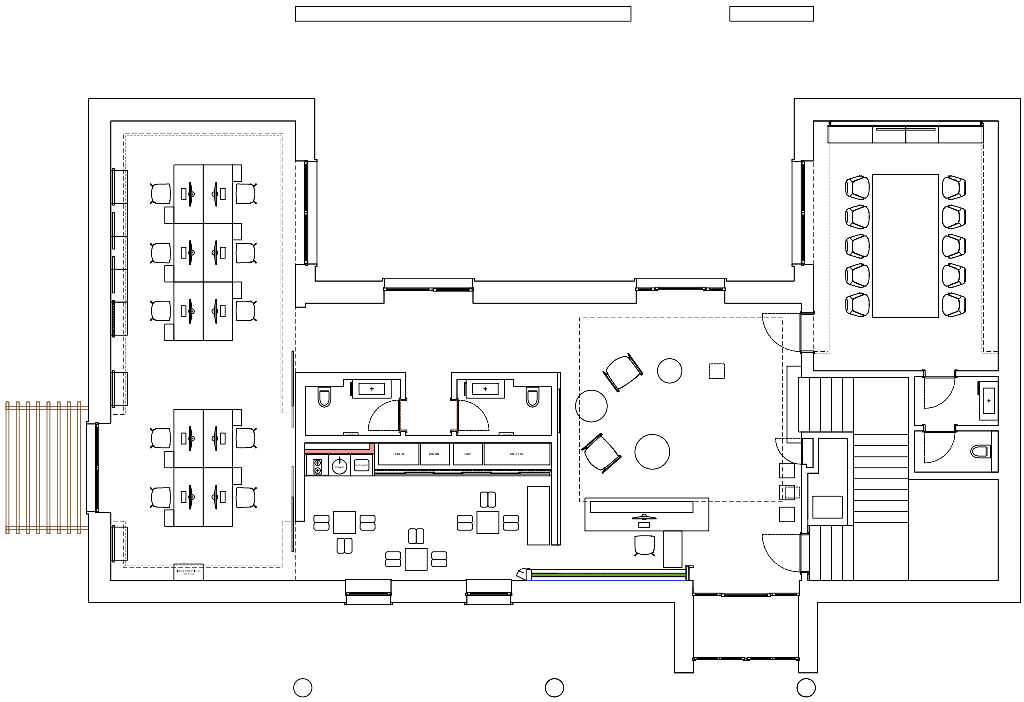


SECTION D-D

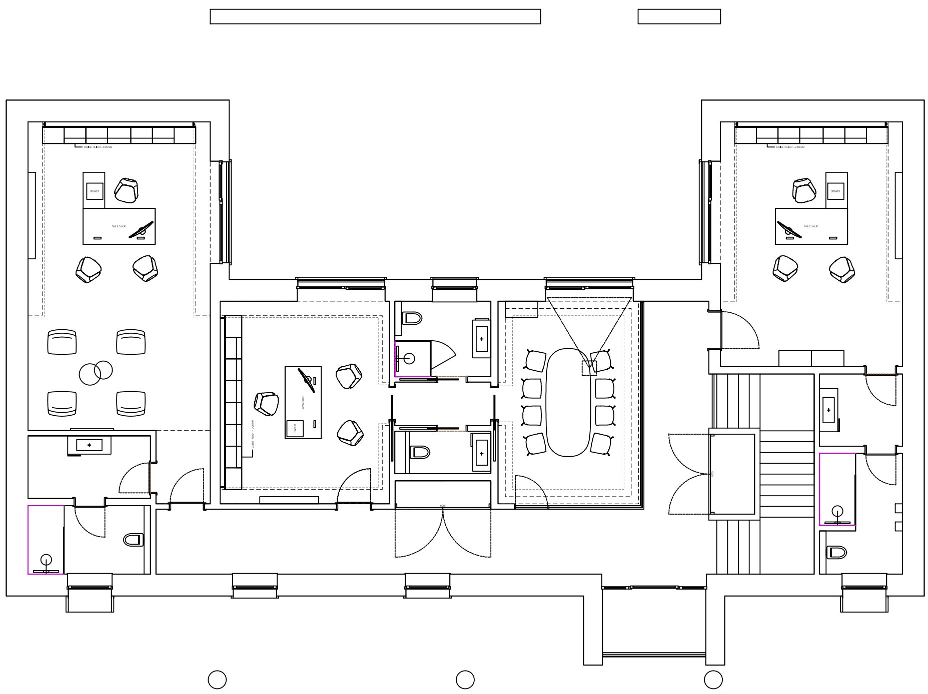


SECTION E-E

4 Floor plans of the Office Building in Al Khawaneej, Dubai



Ground floor plan



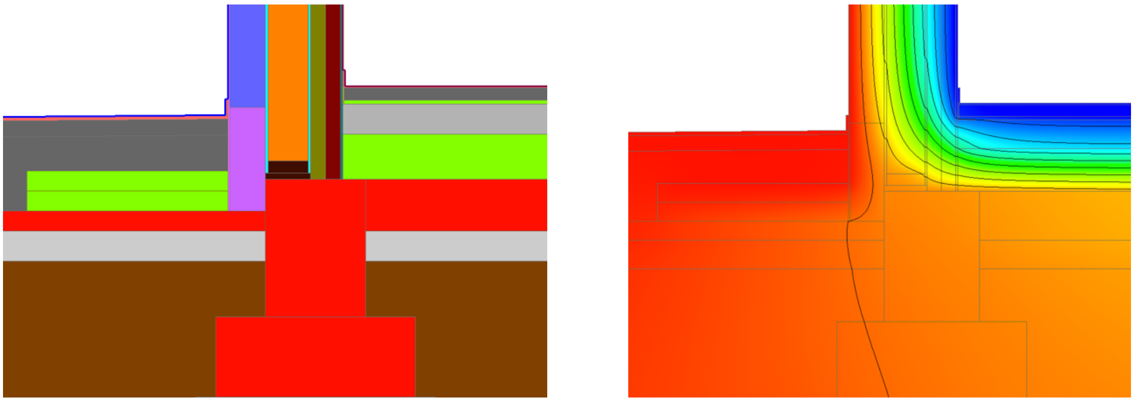
First floor plan

5 Construction details of the Office Building in Al Khawaneej, Dubai

5.1 slab on grade

Stratigraphy (high to low)

tiles	10 mm	U = 0,108 W/m²K
screed + radiant floor pipes	60 mm	
XPS for radiant floor	20 mm	
perlite added lightweight screed	155 mm	
XPS	225 mm	
vapour barrier	-	
concrete	120 mm	



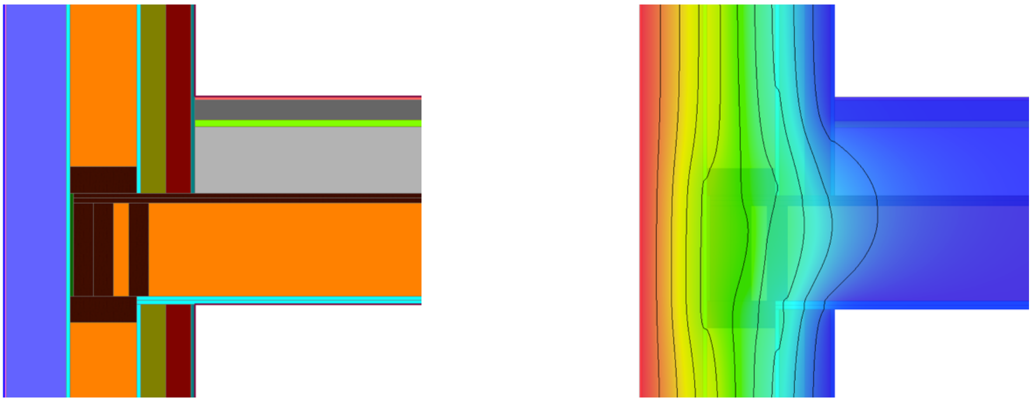
FEM calculation of the perimeter thermal bridge (ψ = -0,064 W/mK)

top left: foundations - bottom left: XPS over BV - right: screeds and tiles

5.2 external wall

Stratigraphy (inside to outside)

gypsum plaster board	12,5mm	U = 0,076 W/m²K (with red layer) U = 0,090 W/m²K (without red layer)
stone wool within dry counter wall steel frame	75 mm	
stone wool (only for part of the building)	75 mm	
gypsum plaster board	15 mm	
stone wool within timber frame	200 mm	
gypsum plaster board	15 mm	
EIFS (EPS)	180 mm	
coating	7 mm	



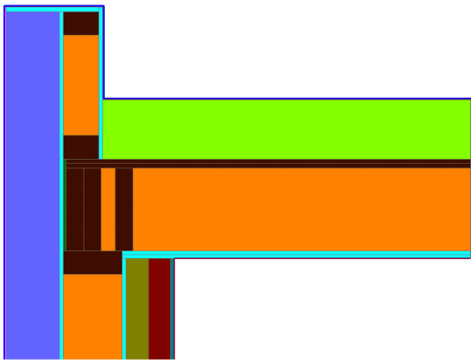
FEM calculation of the wall to intermediate floor thermal bridge (ψ = 0,011 W/mK)

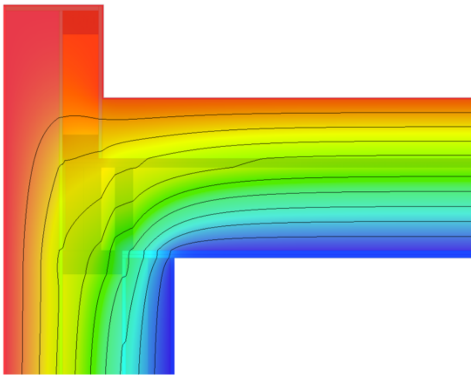
top left: factory prefab at Wolf in Italy - top right: site assembly
bottom left: EPS external insulation – bottom right: counterwall

5.3 roof

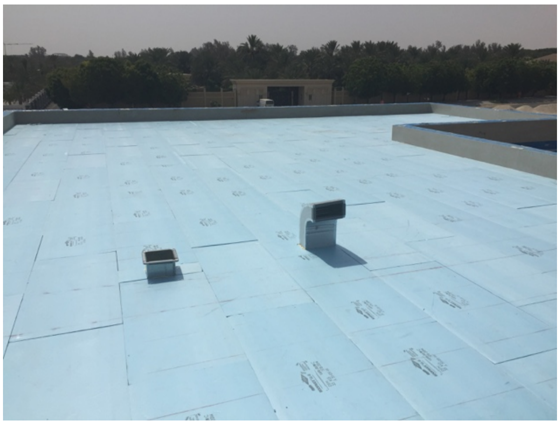
Stratigraphy (high to low)

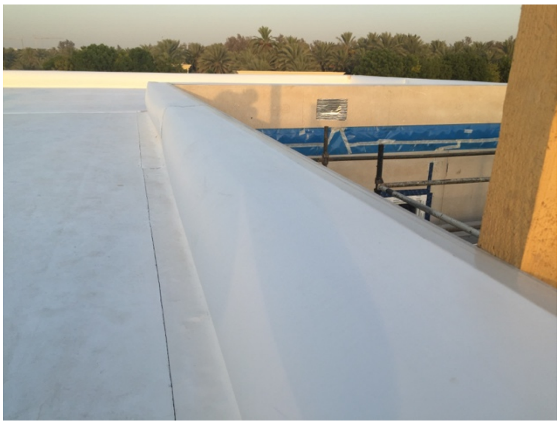
waterproof membrane	-	U = 0,076 W/m²K
XPS	200 mm	
particle board	15 mm	
stone wool within timber frame	280 mm	
gypsum plaster board	15 mm	





FEM calculation of the wall to roof thermal bridge (ψ = - 0,041 W/mK)

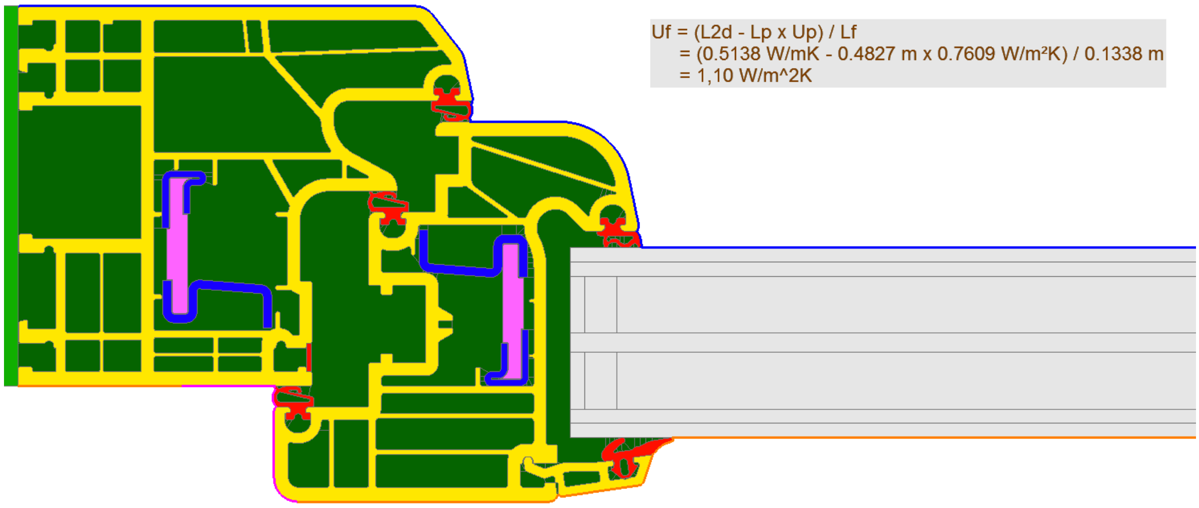




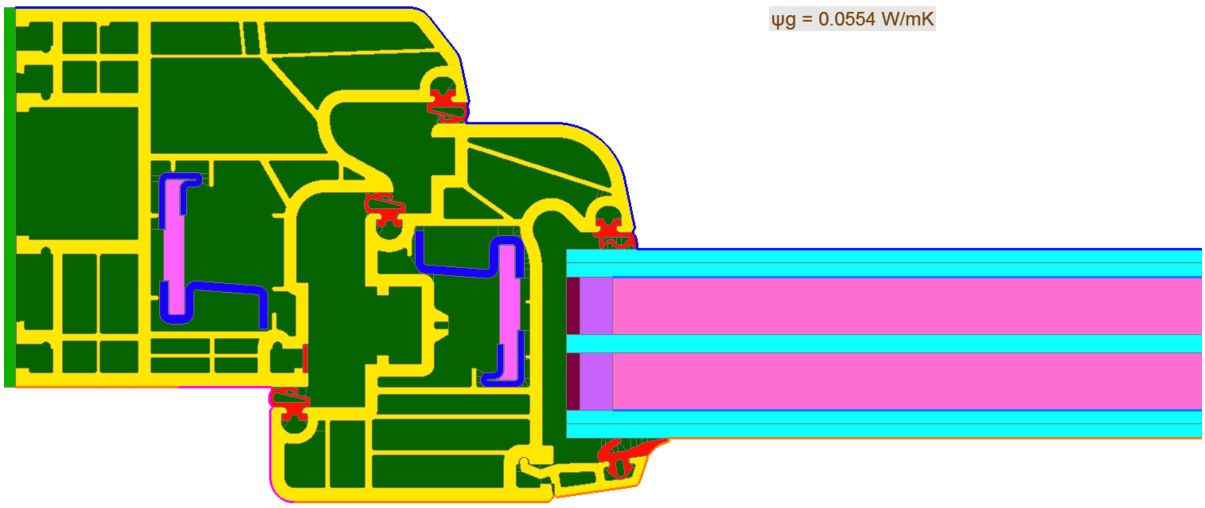
top left and right: XPS over prefab roof
bottom left and right: reflective waterproof membrane

5.4 windows and installation

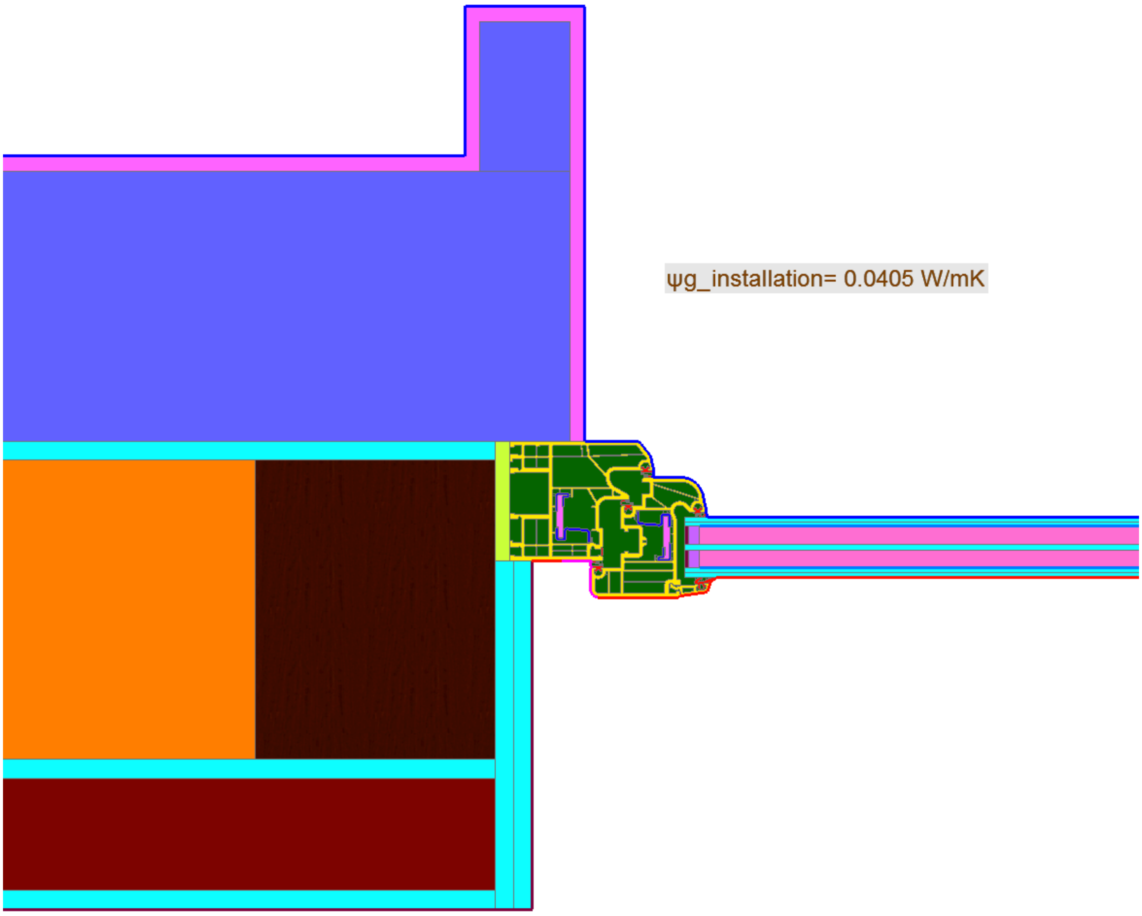
Pvc windows were chosen, except for entrance doors – for which thermally broken Aluminium frames were used to guarantee better durability.
Pvc windows were Bayerwald Fenster Haustüren mod. bw80+ (Uf from 1,06 W/m^{2}K to 1,17 W/m^{2}K), while Aluminium frames were Schüco AWS/ADS 90 SI (Uf from 0,83 W/m^{2}K to 1,45 W/m^{2}K).
Glasses were triple glazed with 90% Kripton filled cavities: 6/12/4/12/3+3 (faces 2 and 5 were treated) – Ug = 0,50 W/m^{2}K, pvc edges (ψ_g from 0,051 W/mK to 0,057 W/mK) and very low g values (0,28) with a still acceptable light transmission (0,44).
All profiles were FEM calculated in order to obtain Uf, ψ_g and ψ_installation values for each node.
An exemplary calculation is hereafter shown:



Pvc lateral frame, Uf calculation according to EN 10077-2.
Cavities are shown in green, steel reinforcements in blue and reinforcement thermal brakes in violet.



Pvc lateral frame, ψ_g calculation according to EN 10077-2.



Lateral installation node of the PVC window, with calculation of the installation thermal bridge. Dark brown is the wall structural timber frame, while gipsum plasterboards are in cyan.

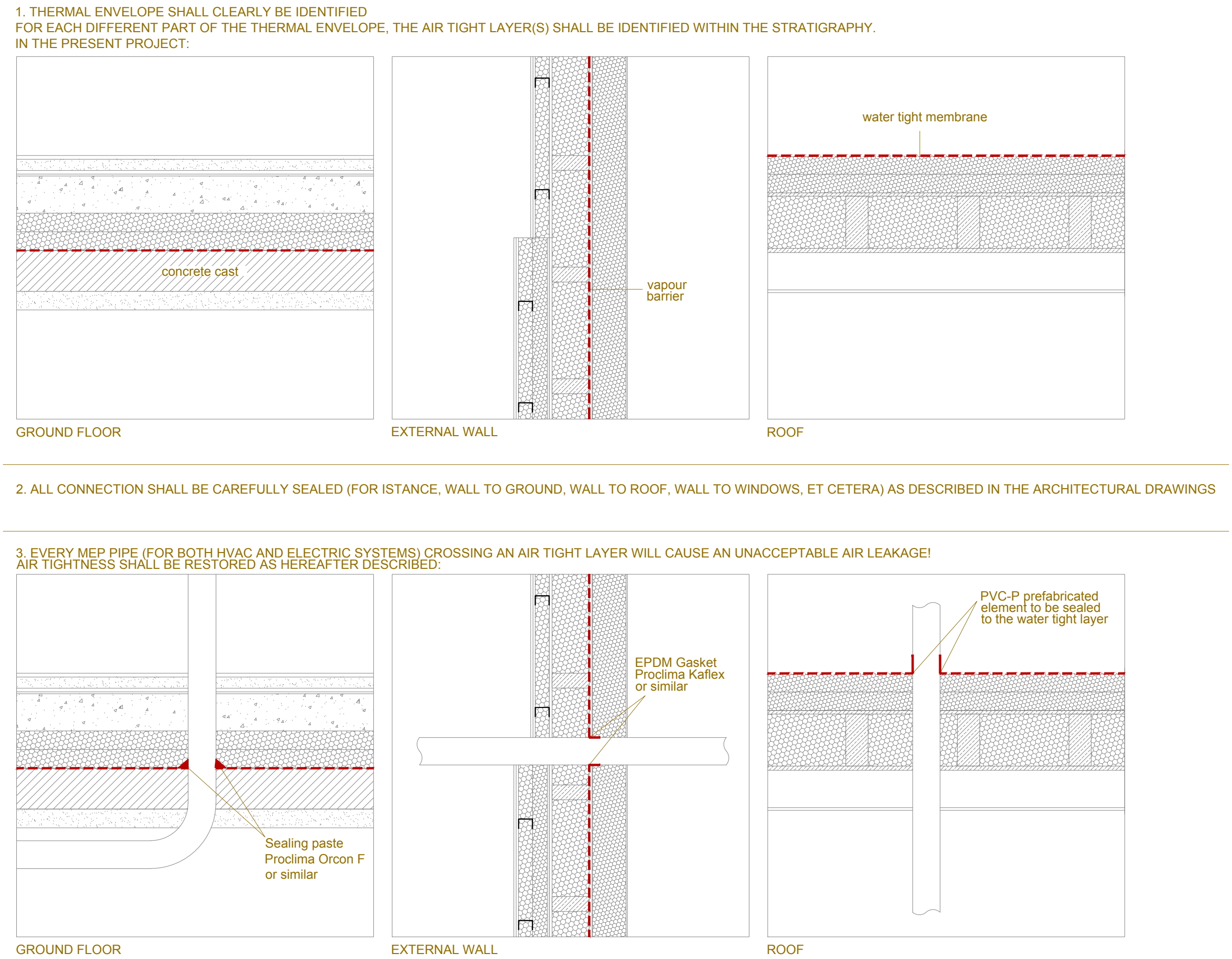
Installation position is in midwall, as the usual business in European passive houses. A more recessed position (i.e. towards the inside of the building) was investigated, which could be useful because of the higher shadow due to deeper reveals and overhang. Advantages in terms of shading were however overbalanced by worse installation thermal bridges and this option was thus rejected.

left: pvc frame taped against the vapour barrier before EIFS laying - right: sliding door frames

6 Description of the airtight envelope; documentation of the pressure test result

Dubai climate conditions are such that there is (practically) always a positive vapour pressure difference from outside to inside. This means that, unlike in Europe, airtight layers should be on the outside instead that on the inside. Internal insulation was also investigated as an option, but revealed to lead to higher costs and unacceptable thermal bridges. It is however a possibility to be investigated for technologies, different from timber platform frame.

Air tight layers were identified in the design process and clearly outlined in the design drawings, together with instruction on how to restore air tightness in case systems elements (such as pipes or ducts) overpassed the air tight layers:



excerpt from design drawings: identification of the air tight layers

All connections between wall prefab parts were sealed by means of tapes and self expanding bands, as well as the connection between prefab walls and the horizontal structures.

The prefab wall parts were transported from Italy to Dubai via ship; wall dimensions were thus limited due to 40 inches containers. This caused a huge number of connections to be done on site. For this reason a preliminary pressure test was carried out to verify leakages.

preliminary pressure test before completion (EIFS, counterwalls, screeds were missing)

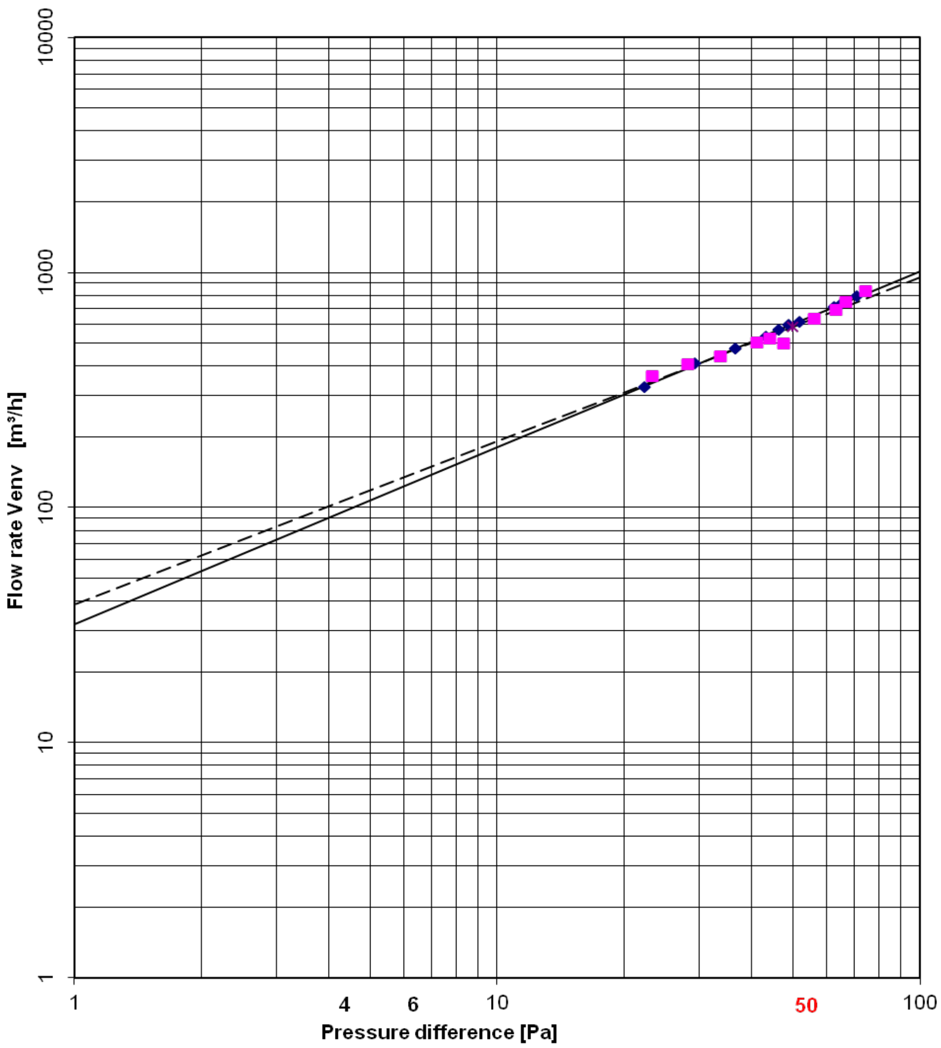
A hot wire anemometer was exploited, together with fog machine. Some minor leakages were found in the connections between walls and intermediate floor, which were real time sealed.
Final test was carried out on end of August, when the building was almost totally completed.

final pressure test at the presence of client (MBRSC) technicians

Results of the test are hereafter reported:

test type	building address and year of construction
UNI EN ISO 9972:2015 - method 1 pressurization and depressurization	Wadi Al Amardi Street Al Khawaneej, Dubai, UAE year 2016
test date	**test result**
29.08.2016	$n_{50} = 0{,}48\ h^{-1}$ (net volume calculation to UNI EN 13829:2002) $n_{50} = 0{,}38\ h^{-1}$ (net volume calculation to UNI EN ISO 9972:2015)

final pressure test result. Noticeably there is a quite big difference in the n50 value if calculated according to the superseded (but still required by PHI) EN 13829 or according to the EN 9972 – the latter being less conservative.



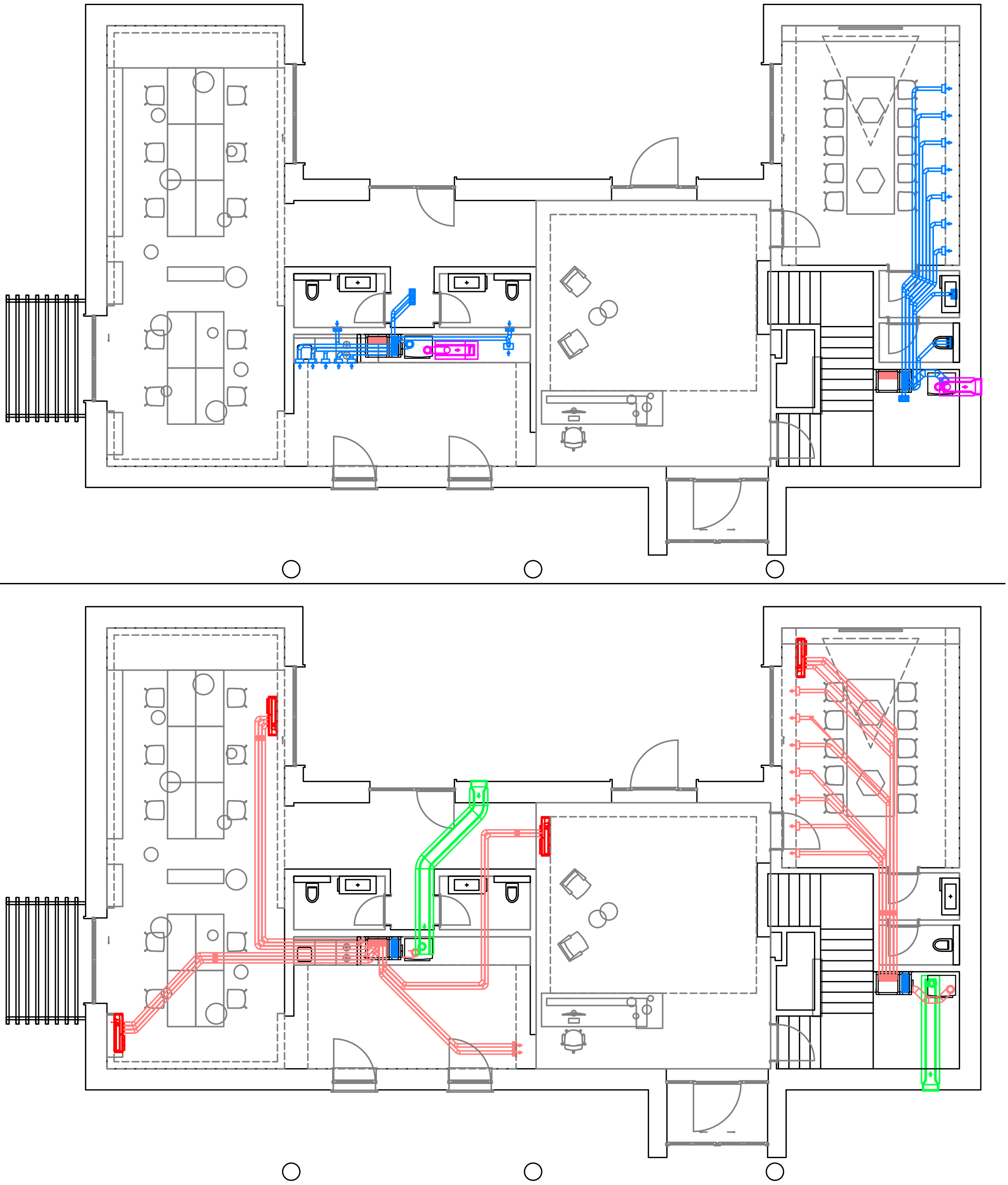
7 Planning of ventilation ductwork

The proper fresh air rate was calculated according to PHI requirement ad ASHRAE 62.1, which is mandatory in Dubai. The ‘classic’ principle of the three zones (supply, transit, extraction) was used to design the distribution system, except for the major meeting room.

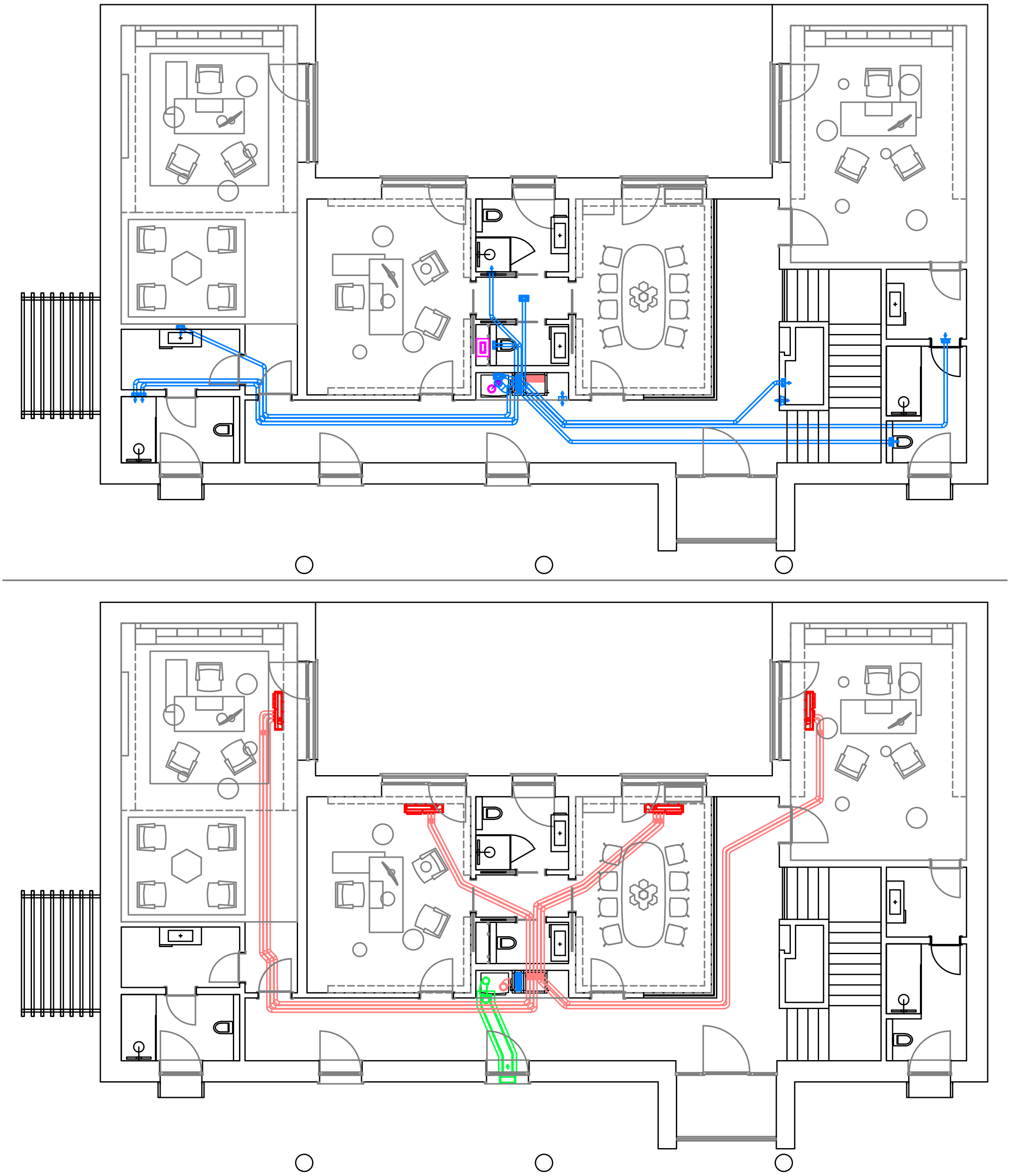
Heat recovery ventilation (HRV) units have been used, with a PHI certified 89% recovery efficiency. Only sensible heat is recovered even if enthalpy recovery could be a good alternative. However, at the moment poor data are made available from manufacturers and this option was thus left unchosen.

Nominal ventilation rates are respected during worktime only. After worktime there is a reduced rate period, to allow for some air exchange during daily cleaning activities; after that HRV units are switched off.

Distribution was realized according to the following drawings:



HRV distribution: ground floor. ODA (green), SUP (rose), ETA (blue), EXP (violet)



HRV distribution: first floor. ODA (green), SUP (rose), ETA (blue), EXP (violet)

HRV units was positioned with the goal of minimizing ducts lengths, both for ODA and EXP ducts (in this case this allows for lower energy losses) and for SUP and ETA ducts (in this case this allows for lower pressure drops and consequently lower electric consumption).
Three ventilation units were used instead of a bigger single unit, for the following reasons:

- more flexibility, for instance the meeting room unit can be operated according to the room's real usage (CO_2 sensor);
- there was little space for systems, so more compact units were easier to place;
- minimize pipe lengths, placing the units in a central position.

HRV units were Paul Novus 450, data are as follows:

Component id:	0303vs03
Manufacturer:	PAUL Wärmerückgewinnung GmbH
Air flow range from:	140 m^3/h
To:	348 m^3/h
Heat recovery rate:	89 %
Specific electric power:	0.29 Wh/m^3
Efficiency ratio:	0.7
Humidity recovery:	0 %
Sound level of unit:	52.9 dB(A)
Climate zones:	Cool, temperate

Leakage

Internal leakage:	1.02 %
External leakage:	0.61 %

Acoustic duct

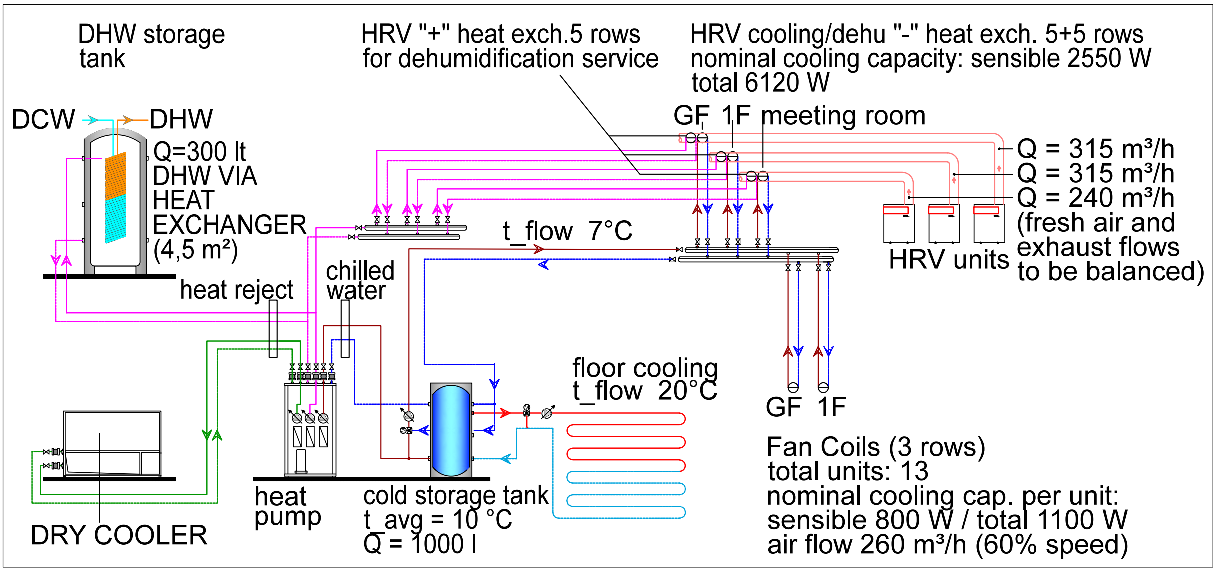
Outdoor air:	57.1 dB(A)
Supply air:	71.1 dB(A)
Extract air:	54.8 dB(A)
Exhaust air:	75.1 dB(A)

data taken from passive house components database: https://database.passivehouse.com/en/components

8 Systems

8.1 Mechanical systems

The mechanical system is obviously focused on cooling. A water / water heat pump with hydronic distribution was designed, as per the following sketch:



sketch of the mechanical systems' functional principle

Cool is generated by a water / water heat pump, with an external dry cooler. The produced chilled water has a design flow temperature of 7 °C, which guarantees air condensation and thus allows to completely cover latent load (being latent load often the higher portion of the total cooling load). Latent load is treated in air / water coils which are placed in the supply air ducts of the heat recovery ventilation (HRV) units. There are 3, PH certified, HRVs with static sensible heat recovery (latent heat recovery was an option but so far no complete performance data are available for such devices); flow rates have been designed to fulfil PH requirements together with ASHRAE 62.1 requirements. These coils are coupled with a second, hot water operated, coil in case pure dehumidification service is required.

In normal cases, as per PH functional definition, treating the incoming external air allows to satisfy the whole latent load and a huge part of the sensible load. However, being the building used as an office, the internal heat gains are pretty high; to face this problem additional fan coils operating at 7 °C were installed to match the uncovered sensible load.

At last, a radiant floor system was installed with a design flow temperature of 20 °C, which is higher than usual design temperature. In fact, radiant floor is used to keep the screed fresh enough (roughly 23 °C). Radiant floor is thus a way to keep masses under control rather than a real cooling system. Having the floor at a controlled temperature, lower than set temperature, allows for lower mean radiant temperature thus enhancing the thermal comfort.

One important feature is the recovery of the condensate. Water drained from coils and HRVs is collected in a 1000 litres storage tank and then re-pumped inside the building to feed toilet flushes. It is also used to periodically wash the sand away from the dry cooler. This is a very important feature considering that there is no soft water in Dubai; in the first two months of systems' operation 7000 litres of water were recovered and reused.

DHW is produced using the heat reject from the heat pump in chilling mode, so from a practical point of view we can say that DHW is produced 'for free' – being the electrical consumption of the circulation pump due in any case, even if heat reject circulates in the dry cooler.

8.2 Electrical systems

The electrical system is based on a building automation architecture with HDL protocol. Other than usual building automation functions, some distinctive features have been designed in order to help minimize internal heat gains pertaining to equipment and lighting. In addition to the exclusive use of high efficiency LED lighting, every working room is equipped with a lux meter to adjust the intensity of artificial lighting, based on actual value of natural lighting. Moreover, venetian blinds are automatically operated and are programmed to completely shut down after worktime. In the same way, after worktime the building automation system cuts off the power supply of electronic devices to avoid any stand-by losses.

top left: room control - top right: home automation user interface
bottom left: recessed sound speakers – bottom right: led lighting

PHPP relevant sheets (Use non-res, Electricity non-res, Aux Electricity, IHG non-res) have been filled with full details, in order to calculate a custom IHG value.

As an example, low consumption computers and cold printers have been foreseen. Client has been informed through a technical report indicating the maximum acceptable values for each electric appliances and electronic devices

Office equipment		Room category	Within the thermal envelope [1/0]	Existing [1/0]		Quantity		Power consumption [W]		Utilisation hours per year [h/a]
		2								9
PC 1		1-23-open space room	1	1	*	12	*	20	* (	2000
PC in energy saving mode			1			12	*	1,0	*	2000

excerpt from Electricity non-res sheet in PHPP. In the open space, computer must have an average power consumption of maximum 20 W. Apple Macbook Pro was used as a reference.

Looking at the electricity production, the building is provided with a PV field composed by polycrystalline silicon modules for a total power of 40 kW, coupled with a 25 kWh electrical storage. The combination of these two systems should allow for energy independency; this design result will be verified with the further described monitoring.

partial view of the PV field

9 PHPP calculations

PHPP version 9 was used in the project. Climate data were custom supplied by ZEPHIR / PHI for this specific project and then made available for the community. Beside PHPP calculation, transient analysis was carried out using both EDSL TAS and TRNSYS.
Result are summarized below:

Passive House Verification

Building:	pilot project "Passive House in Dubai"	
Street:	Al Khawaneej Street	
Postcode/City:		Al Khawaneej
Province/Country:	Dubai	AE-Vereinigte Arabische Emirate
Building type:	office building	
Climate data set:	AE0001a-Dubai	
Climate zone:	7: Very hot	Altitude of location: 6 m
Home owner / Client:	MBRSC - Mohammed Bin Rashid Space Centre	
Street:	Al Khawaneej Street	
Postcode/City:		Al Khawaneej
Province/Country:	Dubai	AE-Vereinigte Arabische Emirate

Architecture:	Casetta&Partners		
Street:	via Verdi, 67		
Postcode/City:	31046	Oderzo	
Province/Country:	Treviso	IT-Italien	
Energy consultancy:	University of Bergamo - Dept. of Engineering and Applied Scier		
Street:	Viale Marconi, 5		
Postcode/City:	24044	Dalmine	
Province/Country:	Bergamo	IT-Italien	
Mechanical system:	Energy Plus Project		
Street:	piazzetta San Marco, 7/8		
Postcode/City:	31053	Pieve di Soligo	
Province/Country:	Treviso	IT-Italien	
Certification:			
Street:			
Postcode/City:			
Province/Country:			

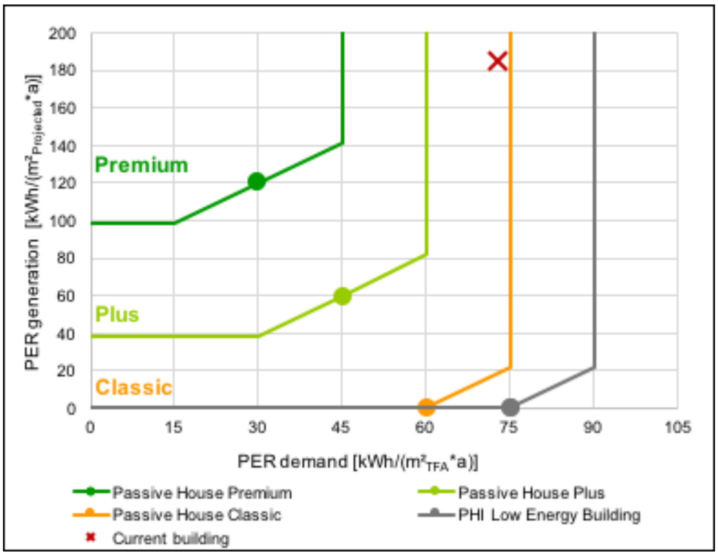
Year of construction:	2016	Interior temperature winter [°C]:	19,4	Interior temp. summer [°C]:	25,0
No. of dwelling units:	1	Internal heat gains (IHG) heating case [W/m²]:	2,8	IHG cooling case [W/m²]:	2,8
No. of occupants:	16,0	Specific capacity [Wh/K per m² TFA]:	84	Mechanical cooling:	x

Specific building characteristics with reference to the treated floor area

					Criteria	Alternative criteria	Fullfilled?[2]
	Treated floor area	m²	410,8				
Space heating	Heating demand	kWh/(m²a)	0	≤	15	-	yes
	Heating load	W/m²	-	≤	-	-	
Space cooling	Cooling & dehum. demand	kWh/(m²a)	50	≤	19	57	yes
	Cooling load	W/m²	9,7	≤	-	10,7	
	Frequency of overheating (> 25 °C)	%	-	≤	-		-
	Frequency excessively high humidity (> 12 g/kg)	%	0	≤	10		yes
Airtightness	Pressurization test result n_{50}	1/h	0,48	≤	0,6		yes
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	143	≤	-		-
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	73	≤	60	73	yes
	Generation of renewable energy (in relation to projected building	kWh/(m²a)	185	≥	-	19	

[2] Empty field: Data missing; '-': No requirement

excerpt from Verification sheet in PHPP



excerpt from PER sheet in PHPP

Despite the huge amount of electricity production, the building fails to meet Passive House Plus requirements due to the fact that the electrical storage is kept in an auxiliary building – unlike what was initially foreseen. In order to guarantee the batteries' durability their installation room shall be kept under 30 °C. A separate air conditioning unit was thus installed and its electricity consumption accounted for in PHPP.

10 Construction costs

Construction costs are roughly 2550 €/sqm referred to the total gross area of the building as a parametric indicator.
It has to be said that benchmark construction costs refer to low tech buildings – when it comes to energy efficiency. Before the 'green building' code was introduced in Dubai last year, standard business was to have concrete blocks with 5 cm of EPS insulation, low quality windows (sometimes even with single pane glasses), no attention paid to the connections and to the air tightness.

In addition to this, it should also be considered that for this pilot project the mechanical system is purposely redundant and the building will undergo extensive field testing with the goal of lowering costs for systems in future buildings.

The main room for improvement consists in the cost optimization: the building we presented here has a very high construction cost, when compared to Dubai's market standard houses' costs. We believe it would have been impossible to have the correct cost optimization at the first PH attempt, because we faced too many unknowns due to the total lack of similar experiences to rely on.