Can a single 2kW Mini-split heat and cool a 100m2 passive house?

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Project description

Location and type of the building

Figure 1: Before Retrofrit **Figure 2: After Retrofit**

The building (Figure 1) was located in Athens, in the middle of Greece and has a mild climate; so the goal was to eliminate the need for conventional heating & minimize the need for air conditioning. It is located in the Papagou Municipality, on the western slope of mount Ymittos. It consists of two units: on the 1st floor there is a 98.80 m2 typical private residence and there was a separate 43.60 m2 storage/boiler room on the ground floor; this one was converted into an office, the HPHI's headquarters.

The enerPHit Plus approach

An EIFS was applied (Figure 2), all thermal bridges were improved; triple glazing PVC and Aluminium windows were installed. Two separate HRV systems (one in the house and one in the office) and a 30 m long ground heat exchanger were installed. During first winter the house was heated through direct pre-heating via the ventilation system. After March 2016 one 2 kW mini-split was installed in the Livingroom of the residence and after August 2016 the second one in the office.

The PHPP calculations

According to (updated) PHPP calculations the energy balance of the building after the renovation was as in Figure 3. The PHPP results showed the following:

- We could heat the house only by pre-heating the fresh incoming air via the ventilation system. The heating load was close to 10 W/m^2 and a 1 kW heat source could heat the residence. This was done during the first winter with good results.

- We need to actively cool the house. The northeast orientation of the building, the good shading with roller blinds in all south, east and west windows, some night ventilation during cool nights and the ground heat exchanger of the ventilation system reduced the cooling demand, but in our warm climate there is always demand for active cooling.

Specific building characteristics with reference to the treated floor area						
	Treated floor area m²	114,6		Criteria	Alternative criteria	Fulfilled?²
Space heating	Heating demand kWh/(m²a)	11,5	≤	15	-	yes
	Heating load W/m²	10,9	≤	-	-	
Space cooling	Cooling & dehum. demand kWh/(m²a)	12,1	≤	16	16	yes
	Cooling load W/m²	9,8	≤	-	11	
	Frequency of overheating (> 25 °C) %	-	≤	-		-
	Frequency excessively high humidity (> 12 g/kg) %	0	≤	10		yes
Airtightness	Pressurization test result n_{50} 1/h	0,6	≤	1,0		yes
Non-renewable Primary Energy (PE)	PE demand kWh/(m²a)	79	≤	-		-
Primary Energy Renewable (PER)	PER demand kWh/(m²a)	44	≤	45	44	yes
	Generation of renewable energy kWh/(m²a)	67	≥	60	59	

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

Figure 3: The PHPP Verification

The proposed solutions for heating-cooling

The first heating period

Figure 4: The after-heater

As already said, we have used the “direct heating via ventilation” solution during the first winter. A 1,3 kW after-heater (Figure 4) was installed in the supply air duct. The system heated the residence pretty good and the consumption was as expected in PHPP. As shown in Figure 5, the total average load was less than 0,5 kW and never over 0,75 kW. The total consumption for heating was as shown in Figure 6.

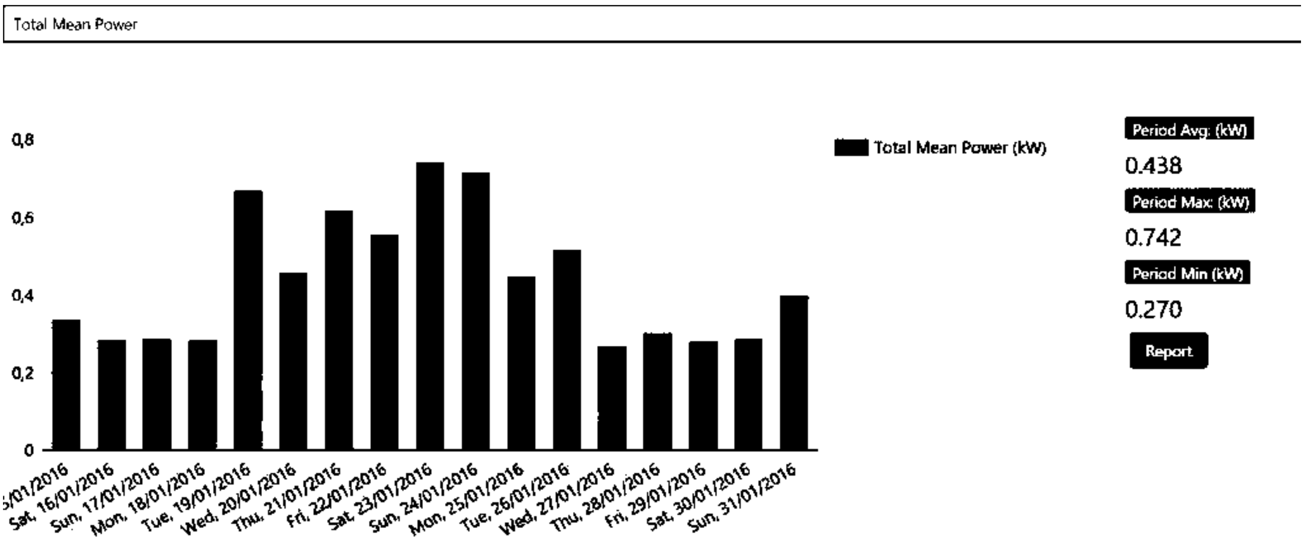

Figure 5: Total mean power for heating during January 2016

Month	TOTAL PHPP	MEASURED	HEATING PHPP	HEATING MEASURED
JAN 2016	689,78	619,35	419,00	367,45
FEB 2016	641,25	388,55	398,00	206,57
MAR 2016	397,78	339,80	183,00	141,35
APR2016	218,01	151,35	15,00	5,00

Figure 6: Results for heating via direct electricity in winter 2016

The cooling period

The proposed solution for cooling the building was to install mini-splits, one in each level. The mini-split (figure 7) for the residence was a 2 kW unit, the smallest we have found in the market, and was installed in the Livingroom. The SEER of the unit was 8,53 !

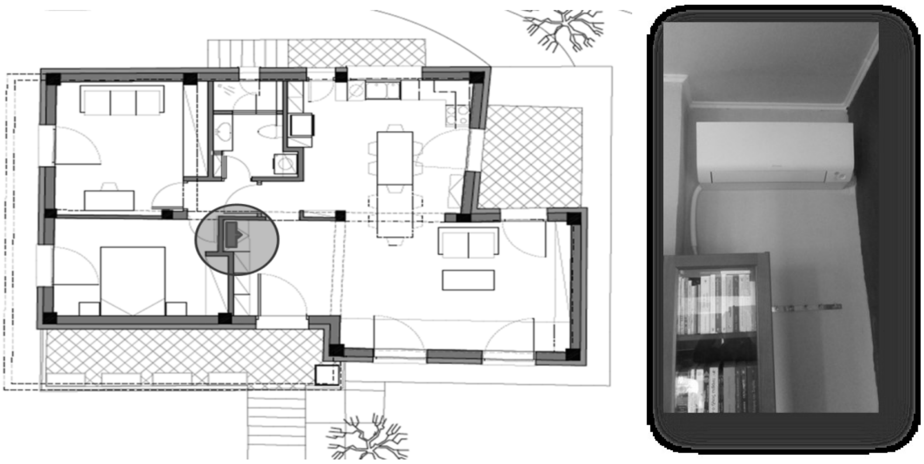

Figure 7: the mini-split of the residence and its position in the Livingroom

The results of the first cooling period were good. The single unit has reached to cool the whole residence without any problem. As shown in Figure 8, the inside temperature in both livingroom and bedroom were clearly under 26°C and the temperature in the bedroom was just 0,5°C higher than the one in the livingroom.

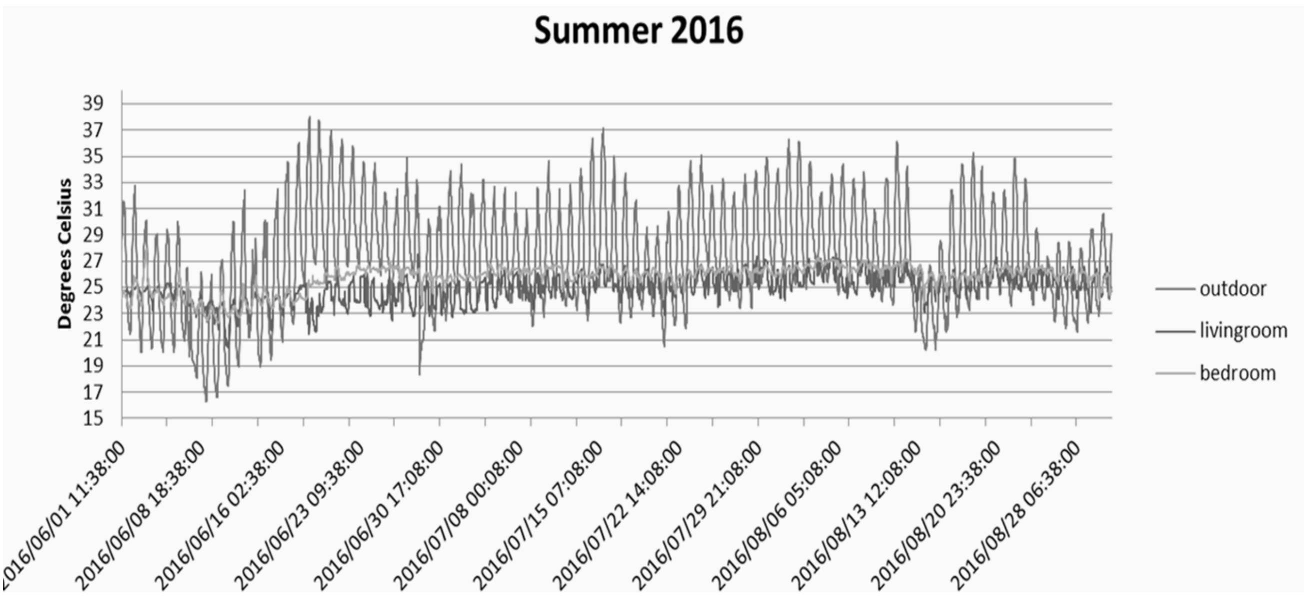

Figure 8: Measured Temperatures during summer 2016

This first cooling period we have done a lot of experiments in order to find the best solution and the optimum consumption. We have often used the “silent mode” of the unit, which reduces its SEER; we have also used the normal mode. Our projection has shown that the performance of the unit was really more than 8 in the silent mode (Figure 9).

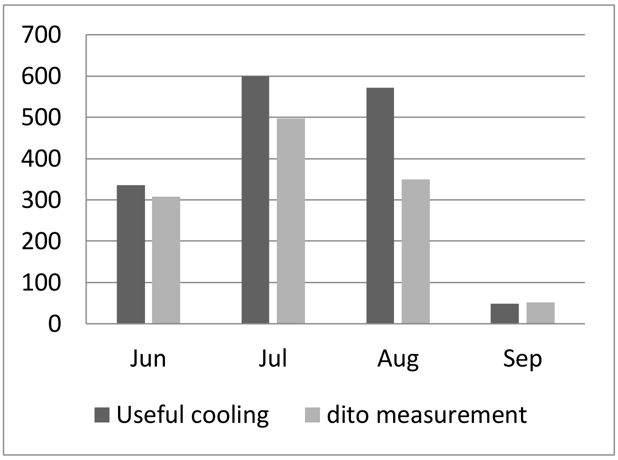

Figure 9: Measurements vs. PHPP

Of course during silent mode the unit had its half of the power, but this was still enough for the house. This is a critical point of choosing the right unit according to the needs of each building: we must always have in mind that in order to avoid unwanted noise during the minisplit operation, we have to choose silent or eco mode, which reduces the performance of the unit. So the unit has to have at least 1,5 times the load comparing to the cooling load according to PHPP calculations.

If we can cool, then why can’t we heat?

During the second winter we decided to also heat the house using only the mini-split in the Livingroom. The thought was simple: if we could cool with one unit, then why can’t we heat with the same unit and reduce the electrical consumption by at least 50%? The calculated average COP was expected to be 3,28, but the real one was a little bit lower. Although this second winter was clearly colder, the average temperature in the living room was over 20,50^{o}C and never under 20^{o}C (Figure 10).

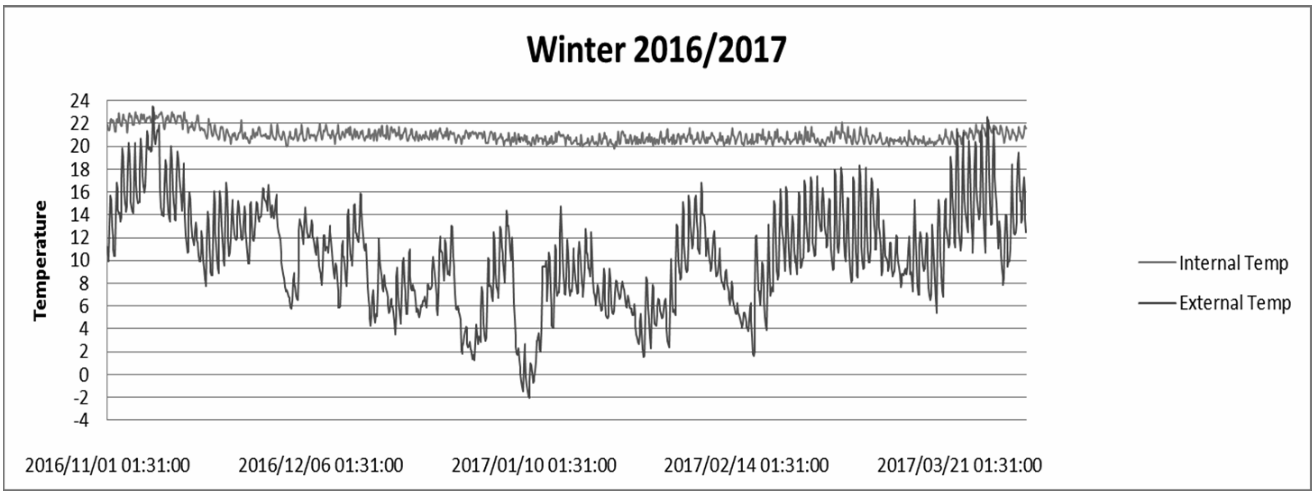

Figure 10: Measured Temperatures during winter 2016/17

Comparing January16 with January17, we can see that although it was colder, the inside thermal comfort, using the mini-split was much better (Figure 11). And of course the daily average consumption was more than 35% reduced, from 14,8vkWh/day to 9,4 kWh/day.

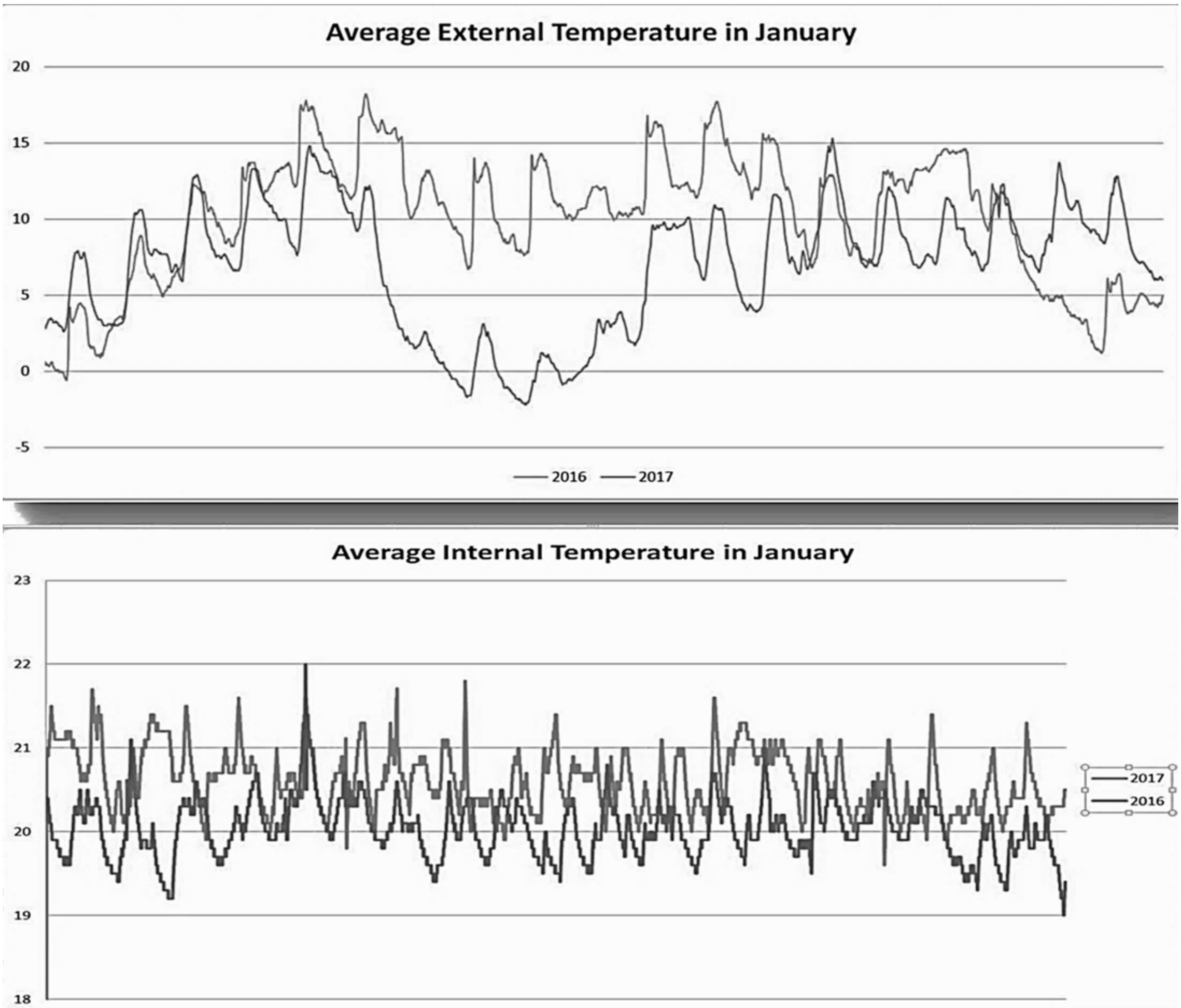

Figure 11: Comparing indoor and outdoor temperatures

Advantages and disadvantages of the system.

There were some important factors that brought these good results:

- The behaviour of the thermal mass of the building showed us that we need to keep a constant situation in the building. We have to keep it always between 20 and 25°C and never leave it cool down during winter or heat up during summer. For this reason we have used some simple automatizations. The unit was always on in heating mode, if temperature drops under 20,1°C during winter. It also was always on in cooling mode, when temperature reached 25,1°C during summer.
- Using the eco or silent mode of the unit was often the right way, if the temperature difference inside and outside was small. This was mainly happening during warm summer nights, where night flushing through windows was impossible to cool the house, because of high external temperature and the thermal mass. So it was better to have closed windows and cool actively, with low consumption because of the low temperature difference.

- This very good performance was of course a result of the appropriate shading, the very good airtightness and the expected performance of the ground heat exchanger (ground heat exchanger performance was more than 85% and 10°C during extreme temperature conditions). Of course doors have to be open inside the house in order to easily cool the total space of it. But even with some closed doors the temperature difference was something like 1°C.

Conclusions

1) In a warm and not so humid climate, like the one in Athens, we always will need active cooling in a passive house. This brings us to solutions like heat pumps. For small residences the use of small heat pumps, the so called mini splits (air-to-air) units is the optimum solution. These units have much higher performance than central units. For small residences, up to 120 m^2, a single unit can cover the demand. For bigger multilevel houses there are products with one external and several internal units which can easily cover the whole house. As a general rule we can say that one unit in the center of each level can cover the demand. A combination of the ventilation system and a mini split , with separated parallel ducts could also be a good solution.
2) If this unit can cover the cooling demand in a warm climate, then it can also cover the heating demand. And this because the building is a passive house, a house that is well insulated, very airtight and with optimum use of solar and internal gains. This brings us to a very important reduction of construction costs (these units are very cheap, easy to install and service) and electrical consumption (because of their good performance and very low losses).
3) The main rule in order to achieve the best performance with mini splits is to keep always the house between the thermal comfort margins (20-25°C) and never leave it cool down or heat up. As this is always the rule in a passive house, it is much easier to reach it with mini splits and some sensors and simple commands via a mobile app.
4) The good results with the use of mini splits for heating and cooling in our climate makes it easier to reach the Passive House Plus and Premium criteria and the NZEB level of the building. The need of energy production from RES is lower and so the cost of installing such a system is reduced. We can easily say that using mini split units in a passive house in warm and warm temperate climates can bring the total construction costs of the building even lower than a Low-energy house.

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Summary

Our project is a stepping stone to NZEB in Greece. Our measurements over the last 24 months proof that we can heat and cool a house with a single minisplit, having met the boundary conditions for thermal comfort and the consumption of a passive house. And all this at a very low construction budget.

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Athens, 4th December 2017 , Stefan Pallantzas

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