Study of Photovoltaics and Solar Thermal for Nearly Zero Energy Mediterranean Villas

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Abstract

The development of modern nearly zero-energy buildings (NZEB) has become possible due to the combination of high quality architecture design and the addition of renewable energies (especially solar thermal and photovoltaic). The Renewable energies can cover all the energy consumption of the year. Solar thermal with Heat Pump and photovoltaic (PV) systems for buildings have been designed to achieve different values of the fraction of primary energy saving. The Flat Plate Collectors (FPC) for Solar Thermal (ST) and Solar Photovoltaic (PV) have to be used in order the system to have higher efficiency with zero energy consumption. 13 different combinations have been studied in order to obtain higher savings with minimum investment.

Keywords: Zero Energy Buildings, Solar Thermal, Photovoltaic, heat pump, combisystems,

1. Introduction

The Article 9 of the European Union Directive 2010/3 which was incorporated in Spanish legislation requires that by the 31st December 2020, all new constructions must be nearly zero-energy buildings. This requires a new concept and a big effort to be made by the construction sector, mainly engineers and architects.

Recently, increasing efficiency of the heat pumps for Heating, Cooling and Domestic Hot Water with decrease in electric PV costs have provided a new model: solar-electric heat pumps. The ST energy has lost installed power during the last few years against other technologies, like PV. The development of modern net zero-energy buildings (NZEB) has become possible not only through the progress made in new renewable energies and construction technologies and techniques, but as well it has also been significantly improved by the combination of heat pump and solar systems (Moià-Pol et alt 2012). There are some simulation programs that can be useful to simulate different combinations of technologies and make it easy to choose the best in each case in order to archive the highest efficiency and renewable energy usage. (fraction). Counting that a modern compression machine with an evaporator up to 7ºC (usually at Mediterranean weather), has a 3-5 Coefficient of Performance (COP), with a Seasonal Coefficient of Performance over 5, and according to the Directive 2010/31/EU it's considered to be similar to another kind of Renewable energy. The actual cost of thermal production with Heat Pump is similar to the Solar Thermal, depending on the working temperatures, refrigerant and quality of the machine (ASHRAE). In Mediterranean areas almost all the villa houses have a swimming pool, Heating Ventilation and Air Conditioning system for a higher comfort. Some of these houses need to warm the outdoor pool in order to extend the swimming period in autumn and spring months, which is translated into a higher energetic demand. This kind of houses according to the Spanish law (CTE) have to use waste energy or renewable energies for the heating system of Domestic Hot Water (DHW) and the pool. For this it´s necessary a bigger installed surface of solar collectors which will allow to take profit of the solar collectors all the year, with a low overheating. However, in order to avoid a big energy consumption, it´s necessary to insulate and cover the pool, and not use it during the coldest Mediterranean months (December, January and February), when the average temperature is lower than 10ºC. The energy of the solar collectors can be used to help the heating system.

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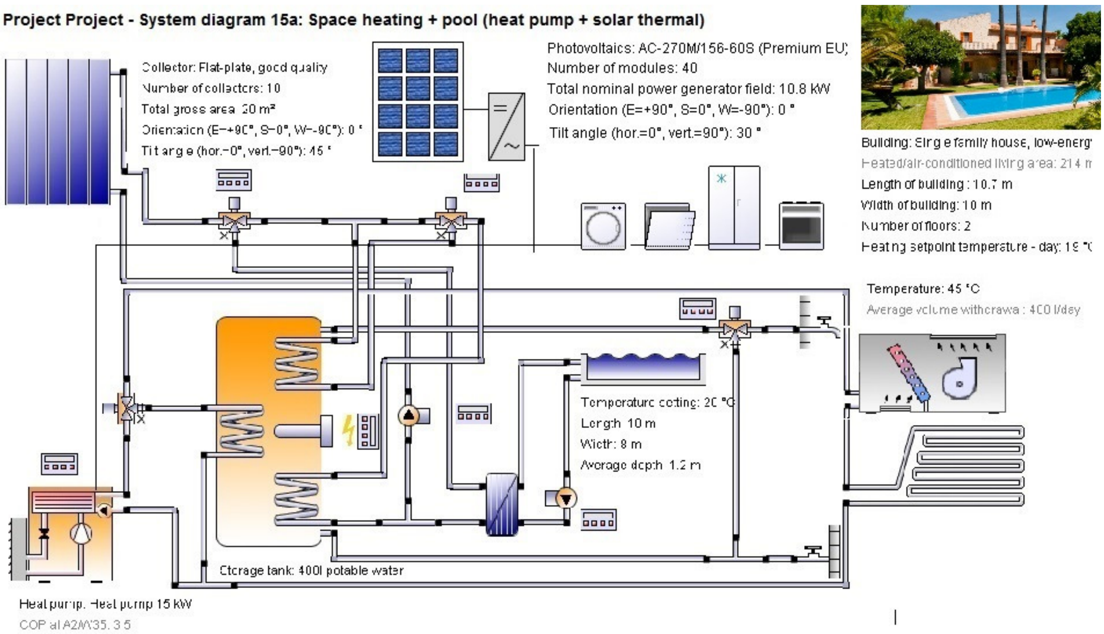

Fig. 1: Thermal system with Polysun

Tab. 1: Annual average temperatures, global horizontal irradiation and Heat Pump C.O.P.for Mallorca

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	*Year*
H kWh/m²	65	79	126	159	196	208	214	188	140	106	66	57	**1604**
Temp.°C	9.4	10	11.1	12.8	16.7	20.6	23.9	24.4	21.7	17.8	13.3	10.6	**16.1**
C.O.P.	3.22	3.26	3.33	3.42	3.54	3.53	3.41	3.39	3.50	3.55	3.44	3.30	**3.41**

2. Simulation and Results

The study case house has a built surface of 400 m^2, of which only 300 m^2 require heating and cooling: the simulation has been made supposing a need for simultaneous heating for 150 m^2 with Fan coils and Radiant system. The pool has a surface of 80m^2 with a volume of 120 m^3. There is a limitation of useful surface for the installation of Solar Collectors -only one roof of 160 m^2 is available. However we have to take into account shadows and the distance between the Solar Collectors which leave us with a useful surface of nearly 80 m^2. This limitation has been taken into account in all the scenarios. The PV system has been designed with monocrystalline panels equivalent to an efficiency of 166 W/m^2 (η =16,60 %) and the solar thermal with good Flat Plate Collectors (A_0 = 0,807, A_1= 3,075, A_2= 0,022) .

The FPC sends the excess of energy to the pool, increasing the set point temperature, and consequently extending the swimming season. In the investment cost there have only been considered the solar collectors, structure, pipes and cables, without storage tank, heat pump and batteries, in order to be able to compare without auxiliary systems or other necessary elements for the basic system. However, PVT system wasn't analyzed due to limited roof surface; the results showed that it was better to use PV and ST systems with higher efficiency. The cost of the PV in Spain for medium systems (5- 20 kWp) is about 1500 €/kWp (including installation work, cable, structure and inverter without storage), similar to other EU countries, like Germany and Italy (source EIA and REN21, 2016), with efficient solar panel (15 to 20%) the price in square meter will be near 300 €/m^2.

Solar Thermal cost varies greatly according to the installation peculiarities (distances, roof,..) and other factors (labor, components,..) . In Spain a pumped system of FPC can cost from 300 to 600 €/m^2 (including pipes, pump and control system). Apart from that we have to add the storage. For Spain a storage system between 50-180 L/m^2 is recommended. Pumped systems until 6 m^2 are very expensive with the thermosiphon being cheaper. For larger systems the bigger the surface the cheaper are the prices per square meter.

The best scenario is a combination between Solar Thermal and Photovoltaic: in our case between 12-16 m^2 of FPC will provide the 16% of all the thermal energy, with almost 100% of the DHW and 31% of the pool and heating system. The PV will provide a 70% of the electricity for the heat pump. PV system has a peak power near 9-11 kWp in order to provide the electricity for the HVAC and use the excess for the rest of the consumption. The FPC has a surface of 16 m^2 and the PV of 58 m^2, almost four times bigger.

The designers are working in two scenarios: the first one connected to the grid with batteries and the other a grid system without batteries in order to have the maximum energy production and less CO_2 emissions. The batteries increase a 33% the cost of the PV system (Gallo et al. 2014). Solar thermal technology has to be designed with storage and the advantage in Spain is that PV doesn’t need storage, the excess can go to the grid free or with a low charge. For this reason the storage is a better option which offers higher savings.

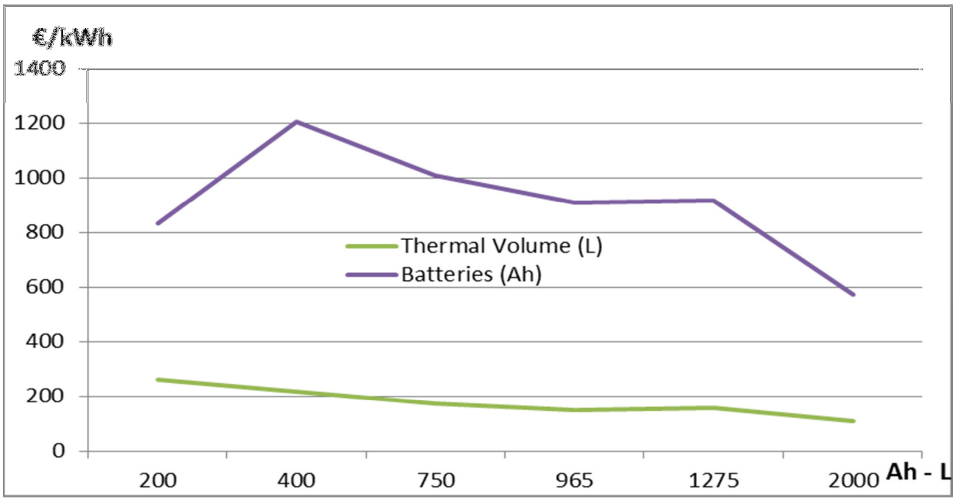

Fig. 2: Cost of Energy Storage Batteries vs. Thermal Storage water (Spanish prices from local suppliers)

In our case, it´s better to increase the storage with thermal energy (water tanks and pool) and install a few batteries in order to increase the self-consumption: the installation cost is 5 times cheaper. Grid parity has been achieved in Spain and the integration of PV systems in nearly ZEB is feasible today (Gallo et alt 2014). The system doesn´t overheat or waste electricity if we provide a good control system. The available roof limits the solar fraction so for higher solar fraction we need a bigger surface or most efficient heat pumps, for instance shallow geothermal or other combinations could be 100% with renewable energies. The PV has a better perspective, for two reasons: the simplicity of systems and the possibility to share the punctual excess (some days or months) to the grid with the net metering policies. Figure 3 has the results of 13 combinations and two different qualities of FPC and PV, Invest (high quality-first brand) and Invest 2 (lower quality-second brand). The Invest and savings are higher when we use the best quality brands. The efficiency of the solar system is the main difference, the initial investment has an average of 18% of difference and the savings are nearly a 47%.

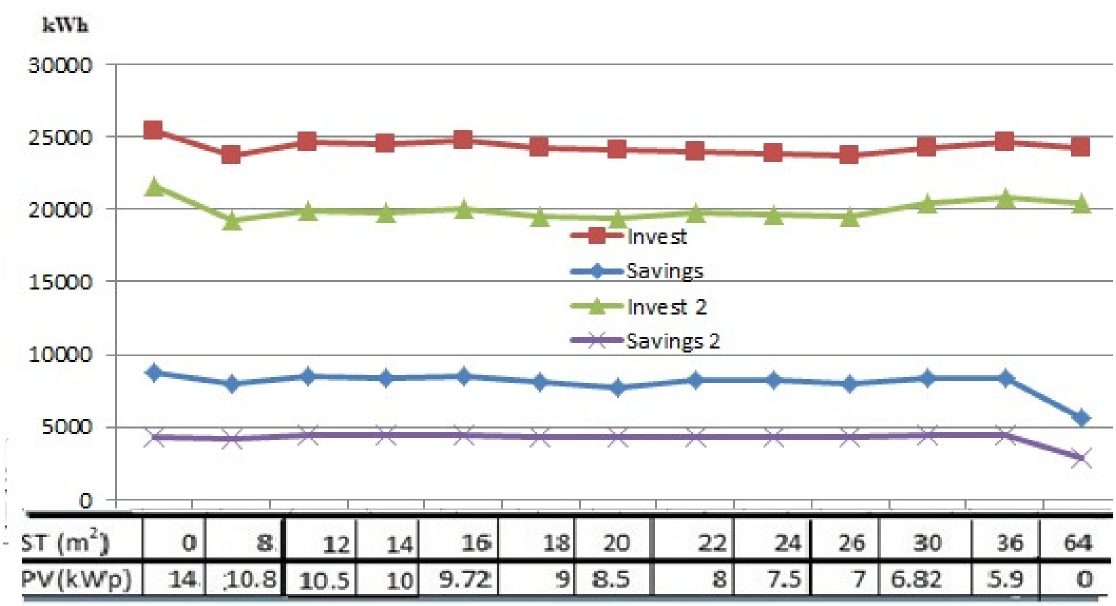

Fig. 3: Energy invest of the solar system (without components) with savings for 13 scenarios and 2 prices

Table. 2: Different studied scenarios with ST ,PV, investment, savings and solar fraction for ST and PV for a Villa in Mallorca

ST(m^2)	**0**	**8**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**30**	**36**	**64**
PV(m^2)	**84**	**65**	**63**	**60**	**59**	**54**	**51**	**48**	**45**	**42**	**41**	**35**	**0**
Invest	25410	23668	24672	24539	24805	24273	24140	24006	23873	23740	24236	24654	24200
Savings	8471	7749	8176	8143	8209	7897	7470	7995	7946	7667	8094	8110	5418
Invest 2	21600	19200	19950	19800	19980	19500	19350	19800	19650	19500	20430	20775	20400
Savings 2	4370	4182	4491	4510	4422	4362	4370	4375	4373	4373	4466	4477	2904
ST (Fraction)	0%	8%	12%	14%	16%	17%	19%	23%	26%	25%	29%	34%	66%
PV(Fraction)	86%	72%	73%	71%	70%	66%	60%	62%	59%	57%	58%	54%	0%

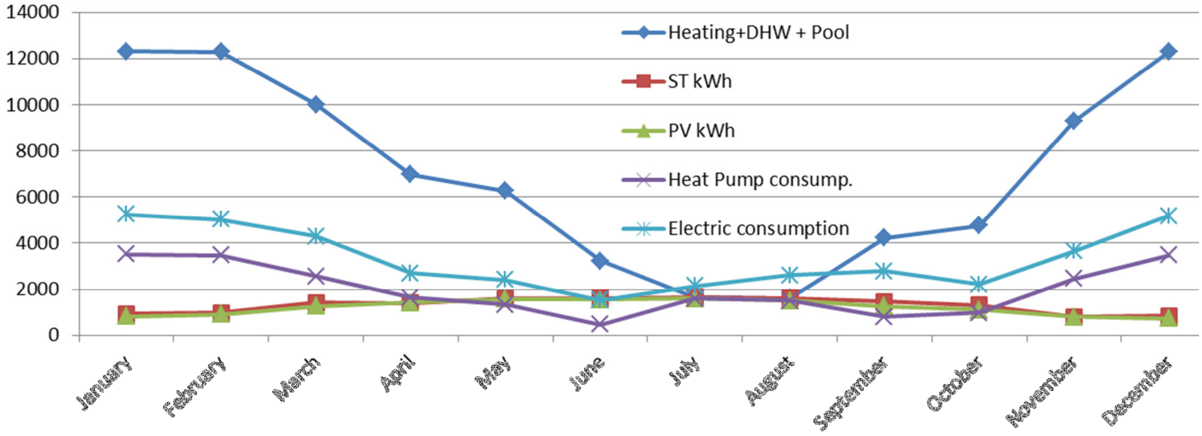

Fig.4: Annual energy simulated results in Final energy [kWh]

The total investment is less than a 5% of the total cost of the villa, which is technically and economically feasible so as to arrive to almost zero energy buildings.

3. Conclusions

The two solar technologies, Photovoltaic and Solar Thermal, are necessary for NZEB from a technical and an economic point of view. The investment cost and savings are better according to the monthly demand. In these cases the best scenario is 14 m^2 of Solar Thermal and 9 kWp of Photovoltaic. Limited space for solar systems make it necessary to use more efficient systems, however with a good control strategy, batteries and overheating systems are not necessary.

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REN21 Renewable Energy Policy Network for the 21st Century. Advancing the global Renewable Energy Transition.