Intelligent Environments 2020
C.A. Iglesias et al. (Eds.)

doi:10.3233/AISE200048

Intelligent Thermal Storage in the Balearic Islands Hotels with Solar Energy

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Abstract. The Balearic Islands are a representative example of tourist islands, with more than 2.500 Hotel and touristic industries, which implies with its approximately a half million available beds, an increase in 50% of the population during high season. High energy consumption in hours with low Renewable energy production represent additional problems. Hotels consume the 15% of the total energy in the Balearic Islands. Data from 27 Hotels was studied in order to investigate the levels of energy consumption and sustainability taking into consideration future zero emissions scenarios with solar energy production. This paper analyses available data concerning energy consumption in hotels, with a focus on Electric demand (most of them from HVAC systems). The main goal is to determine a mathematical model for predicting the energy consumption, and coupling it as much as possible to the solar energy production. To reach this goal, smart buildings can foster energy efficiency and tackle the reduction of CO_2 emissions within the atmosphere. Hotels can guarantee adequate lighting, ventilation, cooling rates, along with other aspects of building demands in real-time. Monitoring and sensing combined solutions with simple and efficient control strategies are the main contributors to advanced sustainable building technology. The implementation of smart strategies such as thermal storage.

Keywords. Energy Audits, Hotel, Energy Efficiency (EE), Solar Energy, Smart Energy

1. Introduction

Buildings are responsible of the 24% global emissions and their CO_2 emissions reductions are a key element in fighting climate change. Within the Balearic Islands, Buildings represent more than 70% of the electric demand, and more than 30% of the total primary energy. Government has approved a plan to decarbonize the islands in 2050 with a 100% renewable energy sources (RES) on the electrical grid.

Nowadays, energy efficiency in buildings is a prime objective for energy policy at regional, national and international level. Especially in Europe, where many new policies have been applied. Energy consumption in hotels is amongst the highest in the non-

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residential building sector in absolute values (an average of 150 kWh/m^2) [9]. This difference lies on the efficiency processes and the unitary consumption of the users (especially in thermal necessities when considering the diverse external temperatures and the divergent comfort temperature between native dwellers and visiting tourists).

Considering the fact that a building's operational costs will grow with time and that problems only get worse unless some actions are taken, there is a clear need for proper building maintenance, refurbishment or retrofitting (upgrading). Such actions should focus on the building's structural elements and installations, which can also improve energy performance and indoor air quality.

The hotel sector is uniquely placed to provide the impetus for change in business behavior within tourism, because of its multiplier effect on guests, staff and suppliers, as well as the central role that hotels play within local communities. Additionally, possible energy conservation techniques for EE and exploitation of RES have a unique demonstration potential and a high exposure to millions of people that visit hotels at one time [8].

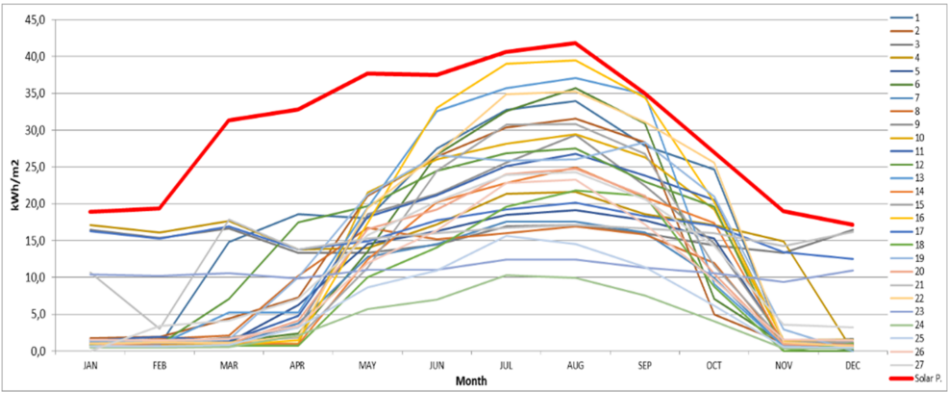

Figure 1. Monthly Energy consumption of different Hotels in Balearic Islands kWh.

Hotels are usually located in areas with high seasonal energy loads, frequently with high energy cost and low supply (i.e. islands). Most of the Mediterranean Hotels have a consumption profile correlated to the solar radiation at summer, especially in August, they have the maximum occupation, when the solar radiation and the temperature reach its maximum values and there are less cloudy days. The energy consumption in the HVAC arrives to most of the hotels to the 50% from the total energy [9]. The solar energy is the easiest to install in the Mediterranean Buildings. The potential form thermal collectors can reach 500-1000 kWh/m^2 year of collector area and for PV 200-400 kWh/m^2 year. Actually less than 10% of the Hotels in Balearic Islands have ST systems, and the implementation of PV in the Spanish Hotels is very low due to until October 2019 there was taxes that make difficult to install, but the last year has start to increase, but is too low to arrive to the Government objectives. 27 Hotels have been analyzed in detail, 70% of them are 4 stars, and the 15% are 3 the other 15% are 5 stars, with the energy consumption by month some results are presented in this paper in order to help

to the Government to apply policies and see the solar potential for these sector. As it can be seen on figure 1, the unitary energy consumption from 27 hotels compared with the solar potential, it seems feasible to arrive to Zero energy buildings with solar energy. Nevertheless, during the month there are several days with low solar radiation, which makes it mandatory large energy storage.

2. Objectives

The objectives of the present article are to estimate mathematical models for the energy consumption in Hotels and afterwards integrate solar energy to reach a real zero CO_2 emissions. The information derived from the energy consumption curves of a given geographical location and the instantaneous consumption of the largest energy consumption sectors of the same area can provide us with a first approach to understand the problems and the possible technical solutions. An in depth analysis of a significant number of energy audits of different industries and buildings can provide us with the necessary information needed for an extrapolation of the energy demand. Furthermore, this will shed light for new ways for energy saving and integration of RES.

For tourist areas, the biggest energy consumer is the tertiary building sector, and especially hotels. However, they usually have a centralized energy production which makes this analysis easier. Energy audits can help hotel companies find out energy management problems and improve energy efficiency, as well as indicating to the government the adequate energy policies to apply.

3. Case study. Balearic Islands

The tourist industry is amongst the most dynamic areas within the services sector, and this is especially the case in Southern Europe (France, Greece, Italy, Spain and Portugal) [9]. The Balearic Islands have historically been one of the primary tourist destinations; there are about half a million beds available, and it is the first destination for Spain. Many successful hotel companies that have emerged during the last few years are now exporting their experience to other expanding destinations.
However, one problem of the Balearic Islands energy model is that it is based on imported fossil fuels [2], only the 3% of the energy is from RES.

3.1. Hotels

The last years have been performed more than 250 energy audits for hotels. These audits represent 10% of all hotel buildings, and their usage sums up to more than 12 million of nights spend. From these audits, we discern that the energy more used in the Islands´ hotels is the electric, owing to 54% of the total energy consumption, while gas and diesel are not used in all the hotels. The factors for predict the energy consumption are de Cooling Degree Days, Heating Degree Days and number of Night Spend.

Table 1 Category of the Balearic Hotels and electric consumption 2017. Source; DG. Tourist. CAIB.

Category of Hotels	Number	beds	Unitary electric consumption (KWh/bed year)	Total Electric consumption (MWh/any)	Emissions (Ton of CO_2)
4* - 5*	368	114.385	2.220	133.353	213305
3*	288	83.242	1.398	61.300	97753
2*	105	15.016	949	7.539	11970
Apartments	933	93.499	650	60.774	51050
Other touristic.	848	146.830	350	51.391	43168
TOTAL	**2.542**	**452.972**	**1.328**	**314.356**	**417.247**

With the increase in standard of living, services that were considered as luxurious now are included in the basic services, as the hotels have improved the buildings and they have increase the facilities, like SPA and acclimatized pools. It is hard to convince hotel owners that even if solar energy or heat recovery systems were used only for heating water that this amount to a saving of more than the 18% of the total energy consumption, as well as a saving in this energy cost, amounts, and a reduction in CO_2 of about one kilogram per night spent. Usually the hotels have three thermal systems, one for DHW and heating another for cooling and other for freezing area. For increase the energy efficiency of the system the Hotels have to change the facilities design and unify the three systems in one, with the maximum heat recovery.

The most important factors that until now with the most influence on the unitary consumption are: the HVAC service and the occupancy.

New generation Heat Pumps with new refrigerants can substitute completely the boiler; they condensation system can work at more than 60ºC and the evaporation system can arrive to -10ºC with high efficiency. For increase the energy efficiency and the Renewable Energy of the system the Hotels have to change the facilities design and unify the three systems in one, with the maximum heat recovery with solar collectors (ST and PV), and for have a large self-consumption the electricity from the PV systems has to be stored most of it thermal tanks (heating and cooling) and a few amount in batteries.

The usual ice storage system with compression machine are working during night time when electricity prices and the ambient temperature are low [11]. This energy may come from wind energy that is not used during night hours. The stored cooling energy is then used to cover peak cooling demands in the afternoon of the next day. Recent studies indicate that solar electric compression refrigeration and solar absorption refrigeration are the solar cooling options with the highest energy saving potential [12]. Both technologies can complement each other very effectively. During peak hours of cooling demand and solar radiation, the solar production is at its highest point, and solar absorption provide its maximum power. On the other hand, ice generation during night is the most feasible way of storing excess night energy to help tackle cooling demands during days of low radiation but excessive ambient temperature.

In our case the system will be working during the day time when the solar energy radiation is higher and store the heat and cool energy. In the hotels will be necessary to use Ice Storage Systems, in this way we can unify Air Conditioning(AC) systems with refrigeration and decrease the storage volume. On the other hand, the close coincidence of the maximum solar radiation with both the cooling loads and the peak electricity demand indicates that solar assisted refrigeration may be an interesting option to handle successfully the issue of reducing peak electricity demand due to air-conditioning.

Glycols systems can be used as well, but with an increasing of the volume storage, without Ice the storage has to be 5 times higher. The option of simple electricity compensation of conventional cooling installations by electricity from grid connected PV panels has its advantages and disadvantages when compared to solar thermal absorption cooling. In order to increase the self-consumption and a high thermal storage reducing the electric storage more expensive than the thermal, has been simulated an Optimal system integrating all the thermal systems in one system with heat and cold storage. Heat recovery from the HP with ST will reduce to zero the DHW from fossil fuel consumption. The PV combined with cooling storage will reduce to zero the cooling and freezing consumption. The heating consumption could be reduced to zero with HP with ST and PV. The other electric consumption will have to implement smart strategies, but a few percentages will have to be stored in batteries or in other technologies like Fuel Cell with Hydrogen and Hydrolysis, in order to arrive to highest self-consumption system, avoiding as much as they can the injection of electricity to the grid, and zero fossil fuel consumption.

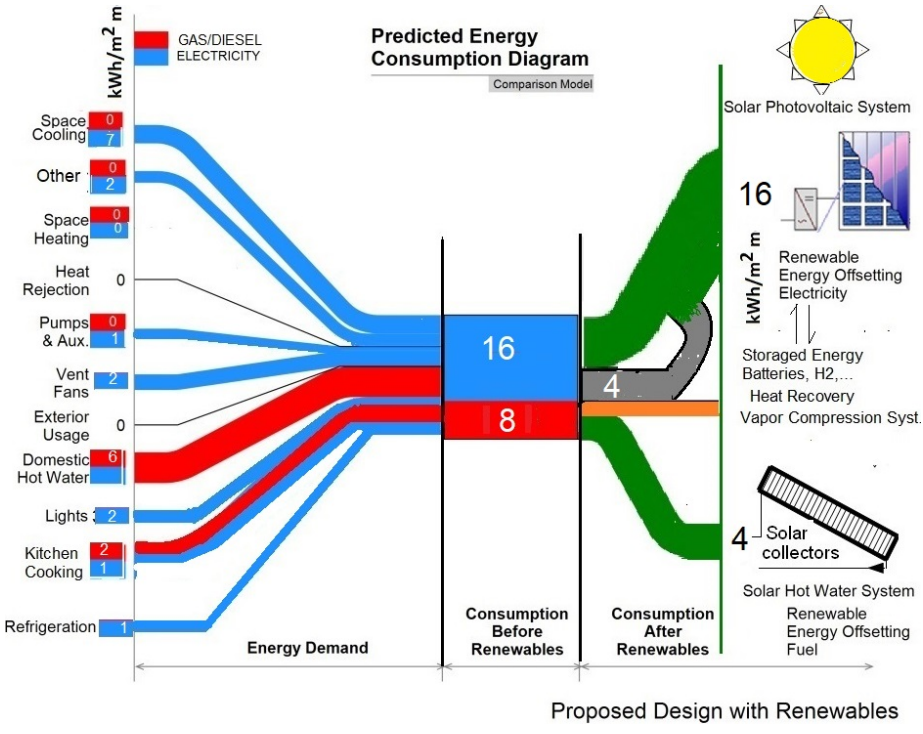

Figure 2. Energy Sankey diagram in a Hotel at Balearic Islands in kWh/m^2 in August.

See at the figure 2 the Sankey diagram with the new model in August, the highest energy consumption month in the Balearic Islands Hotels and in most of the Mediterranean hotels, when the temperatures and solar radiation are higher. The annual average energy consumption is about 150 kWh/m^2, and in August the average is about 24 kWh/m^2 and can arrive to 40 kWh/m^2, see at the figure 2 the new smart energy production in the hotels. The hotels will need between a 10 to 20% of the total surface with solar collectors in order to arrive to zero emissions.

Table 2 New scenario of the Balearic Hotels with Zero Emissions at 2050.

Category of Hotels	Number	beds	Consumption (MWh/year)	PV MWp	ST m^2
4* - 5*	368	114.385	133.353	212	343.155
3*	288	83.242	61.300	97	208.105
2*	105	15.016	7.539	12	30.032
Apartments	933	93.499	60.774	51	93.499
Other touristic.	848	146.830	51.391	43	73.415
TOTAL	**2.542**	**452.972**	**314.356**	**355**	**748.206**

With the real energy consumption from 2016, with the new scenario, the new consumption could be proportionally to the solar radiation, using Thermal Storage and some chemical storage (Batteries, Hydrogen,..). The highest use of electricity is destined principally for air conditioning which makes the energy consumption per night spend vary during the year, this consumption could be easy stored in buffer tanks and used to make an intelligent control.

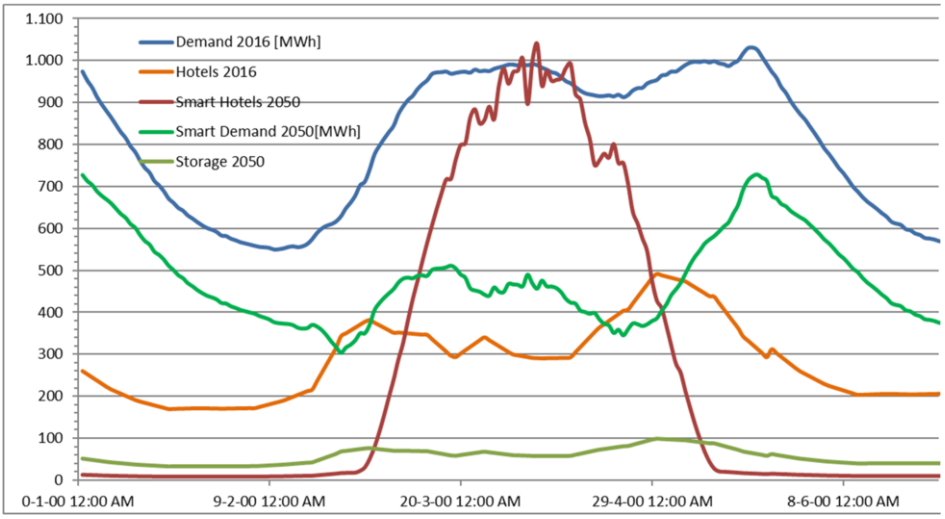

Figure 3. Simulation of intelligent Hotels with thermal storage at Balearic Islands Electric System in August.

In a future scenario with hotels with 100% with solar energy the demand of the Electric system will be reduced in some hours a 50% and in others a 30%, reducing the impact of the tourism in the Energy system. Only with competitive technologies, is possible to

arrive to Zero emissions in 2050, but these will need a total refurbishment and new design of the energy systems in the Hotels and in the rest of the buildings.

4. Conclusion

Applying a smart systems and Solar Energy to the hotels can result in a large economic, energetic saving and a reduction in CO_2 emissions without change in client comfort and increase the RES integration, especially the Solar PV systems. By changing from fossil fuels for renewable energy sources (like photovoltaic and solar thermal), we can arrive at zero or even negative building energy. Promoting and investing on renewable energies to combat CO_2 emissions is the way to stop to discharge more than 350,000 tons per year with a properly electric mix. The overall zero balance in the Balearic Islands system is overall positive in the order to cover Tertiary sector consumption.

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