100% renewable energies at Majorcan Hotels

Andreu Moià-Pol[1], Víctor Martinez-Moll[1] and Vincent Canals[1]

[1] GREEN, Engineering and Construction Department, Universitat de les Illes Balears

Cra Valldemossa km 7,5. 07122, Palma (Spain)

Abstract

The Balearic Islands have to decarbonize by 2050 the Majorcan tourist sector, whose priority will be to change before 2030 the fossil gas and diesel consumption. This paper analyses how to perform the change of fossil fuels in hotels to renewable energy, with a special focus on how to convert all energy demand with renewable energies. The goal is to determine a new model of designing new energy systems, and coupling it as much as possible, to the Solar Energy production with the energy demand. The Hotels can guarantee good comfort with 100% of renewable energies, especially with solar thermal and photovoltaic systems combined with heat pumps and Hydrogens systems. The implementation of high solar fraction combined with other renewables energies will be considered. New design with advanced sustainable building technology could arrive to zero emissions buildings or positive energy.

Keywords: Decarbonization, hydrogen, solar energy, Heat Pumps, Hotels

1. Introduction

The Balearic Island's government wants to achieve zero emissions in the tourist sector by 2035, some Hotels being the first ones to make a step towards this energy transition next year. The effort to decarbonize the Islands will be reached on one hand in each building and on the other hand at electric and gas systems, with high renewable fraction. Renewables in Spain reach a share close to 47% of Electric production in 2021 and a production of 10% more than 2020. The gas sector is planning in the future to increase the fraction of biogas and H_2 input to the net, but some new designs and materials will be necessary for this implementation. Actually, there is an interesting project GREEN HYSLAND which will also deliver a roadmap towards 2050 that compiles a long-term vision for the development of a widespread H_2 economy in Mallorca and the Balearic Region, in line with the environmental objectives set for 2050. A fully functioning H_2 ecosystem in the island of Mallorca is intended to be deployed, turning the island into Europe's first H_2 hub in Southern Europe. This can be achieved by producing green hydrogen from solar energy and delivering it to the end users, such as the island's tourism, including gas grid injection for green heat and power local end-use. Indeed, hydrogen will help to increase the penetration of renewable energy in the Balearic energy system, demonstrating how the Tourist sector can move towards a full decarbonization of the economy.

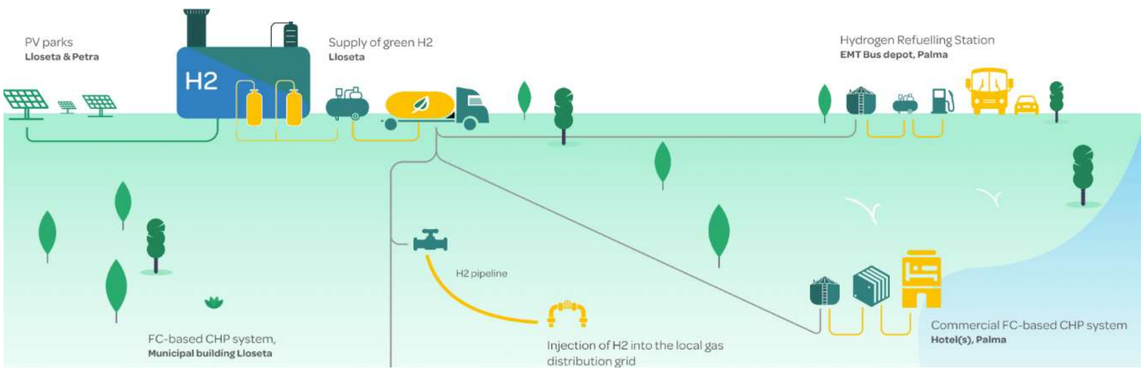

Fig. 1: Greenhysland scheme project. Source https://greenhysland.eu/

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2. Hotels with 100% of renewable energies

Currently in the Balearic Islands, where the largest Spanish hotel holdings are located, a great effort on key issues of sustainability and circular economy is being set up, such as waste disposal, energy generation, consumption of local products and welfare issues. In the first step of this strategic conversion, the Spanish hotel holding companies are putting in place systems of circular economy systems, the commitment to generate decent and sustainable jobs commented in the studies of Esther González Arnedo and others.

The annual average energy consumption in a Mediterranean Hotel is about 150 kWh/m^2, with a 50% of fossil fuels for thermal uses according to the studies of Moià-Pol et Alt., and another 30% for the rest of thermal uses with electricity (cooling, refrigeration,etc). The usual design for the thermal demand of a hotel is a boiler (diesel or gas) for Domestic Hot Water (DHW) and heating, gas for kitchen devices and a Heat Pump (HP) for cooling, a small refrigeration system for freezing rooms with electricity. The last years in order to increase the energy efficiency and reduce de fossil fuel consumption, hotels are changing the facilities design and are unifying the thermal systems - heating, cooling and hot water- in one by changing the conventional fossil fuel boiler for Biomass boiler combined with solar thermal systems or by using only electricity produced by photovoltaics.

PV and wind power combined with HP could provide for the majority of the demand of energy. Some thermal uses such as natural gas kitchen devices could be changed actually by electric or in the future with Hydrogen produced by renewable energy sources.

Wind power presents certain challenges in the building integration and most of the Biomass is produced in other areas and with external suppliers, and sometimes it results expensive to use and maintain. Mediterranean areas present a huge solar potential; thermal collectors can reach up 500-1000 kWh/m^2 year and PV 200-400 kWh/m^2 year. The renewable mix have to be chosen according to the technical complexity of the installation and the monthly energy profile. Hotels which are open all year round and need a bigger thermal fraction, they can use biomass whereas those which open only at summer could be designed only with solar energy and a properly storage system.

The new legislation of the Insular Consell of Mallorca (CIM) wants to reduce the energy consumption of the Hotels with the following rules:

- Energy label of A or B.

- Have a minimum of 50-70% of self-consumption produced by renewables energies.

- The 70% of the Domestic Hot Water has to be heated with Solar energy.

The methodology of this work has been to collect real data from 200 hotels and find the best real rehabilitation practices in approximately 20 hotels, renovated in the last 5 years, as well as data from manufacturers and installers in the Balearic Islands. The main consumptions and the analysed designs are commented below.

2.1. Domestic Hot Water

The new generation of Heat Pumps with new refrigerants (R290, R32, R744,..) can substitute completely the boiler for hot water; the condensation system can work more than 60ºC with high efficiency and the evaporation system can arrive to -10ºC with high efficiency, the main problem is economically being still expensive, due to an emerging technology with high pressure compressor. In order to reduce the initial, even conventional Heat Pumps or Simple effect absorption units could be used until 55ºC but they need to supply a fraction with other technologies for increase the temperature up to 60ºC, in order to reduce the bacteria in Hot Water (especially the Legionella), high solar fraction systems have been studied by Vassiliki Drosou et alt. some years ago in Mediterranean countries with solar thermal fraction up to 70%. Another option is to combine standard HP with small new HP with high temperature or Hydrogen or Joule effect, always combined with PV.

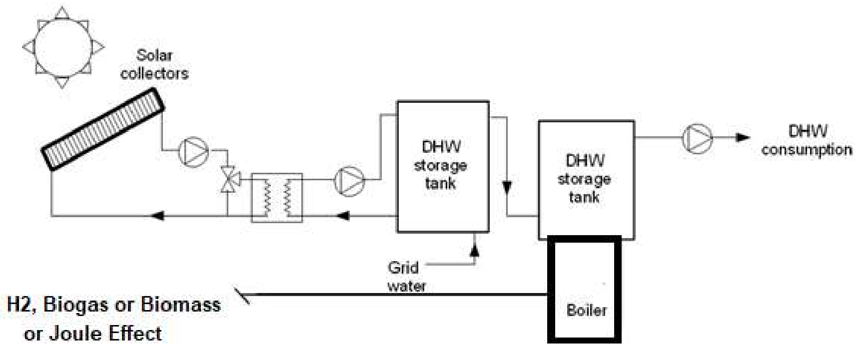

Fig. 2. Example of a system with Solar Thermal energy

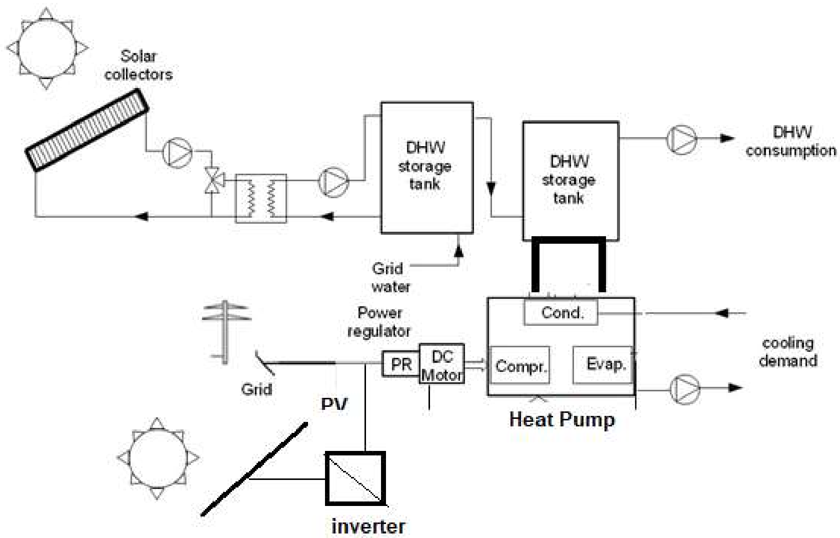

Fig. 3. Example of a system with Heat Pump, Solar Thermal and PV energy

There are a lot of combinations of these technologies, and each hotel, according to the surface t and he level of the maintenance staff could be different. Different combination from real cases has been studied by Moià-Pol et alt. with an estimation of energy cost and CO_2 emissions see at the table 1.

Tab. 1: Renewable mix for Hotels with different fraction for DHW

DHW Generation	ST	PV	HP_Low	HP_High	Joule	€/MWh	kg CO_2/m^2
Natural Gas/Diesel	0%	0%	0%	0%	0%	85	13,5
ST-Natural Gas	70%	0%	0%	0%	0%	40	4,1
ST-PV-Joule effect	70%	30%	0%	0%	30%	32	0
ST-PV-HP_low_Joule	70%	30%	25%	0%	5%	22	0
ST-PV-HP_low _high	70%	30%	25%	5%	0%	21	0
ST-PV-HP_High	70%	30%	30%	30%	0%	24	0
PV-Joule	0%	100%	0%	0%	100%	65	0
PV-HP_low_Joule	0%	100%	80%	80%	20%	34	0
ST-PV-HP_low_high	0%	100%	80%	20%	0%	28	0
PV-HP_high	0%	100%	100%	100%	0%	37	0

2.2. Heating and Cooling Systems.

The last years some hotels have changed completely the Heating and cooling systems, changing the diesel or gas boiler for heat pump, with 100% of electrict consumption (Power to Heat), combined with PV fraction, (figure 4), in mediterranean countries the standard heat pumps with air have a good efficiency all the year even at winter. The PV combined with cooling storage will reduce to zero the cooling and freezing consumption, and is a very easy technology. The other electric consumption will have to implement of smart strategies, but a small percentage will have to be stored in batteries or in other emerging technologies like Fuel Cell with Hidrogen and Hydrolysis, in order to arrive to a highest self-consumption system, avoiding as much as possible the injection of electricity to the grid.

As we have commented before, always the most efficient technology is solar thermal systems, with a higher efficiency and less surface than the PV systems, even if we combine them with high efficiency heat pumps.

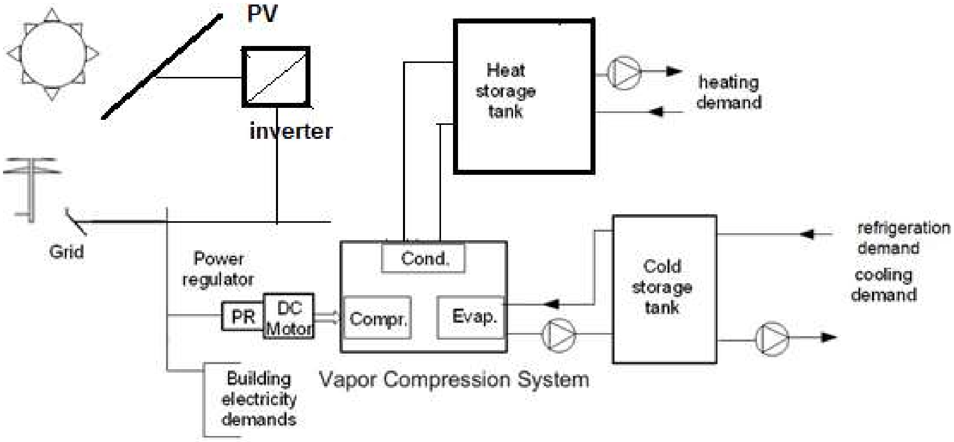

Fig. 4. Example of a Heating system with 100% electric system (Power to Heat)

The ideal system for high thermal loads could be 100% thermal system, with a large Solar thermal absortion refrigeration and a less investment and less generation cost almost 30%, but unforntunately few buildings have large solar systems in their designs.

However, in most of the hotels, specially the ones that open half year or have a high consumption only at summer, the compression systems with PV are better because they can do net metering or sell the overproduction of the PV, the ST will be intersting in areas with District Heating, but unfortunately in the Balearic Islands there isn't any touristic area with DH. In order to increase the self-consumption and a high thermal storage reducing the electric storage which is more expensive than the thermal, an Optimal system has been designed integrating all the thermal systems in one with heat and cold storage.

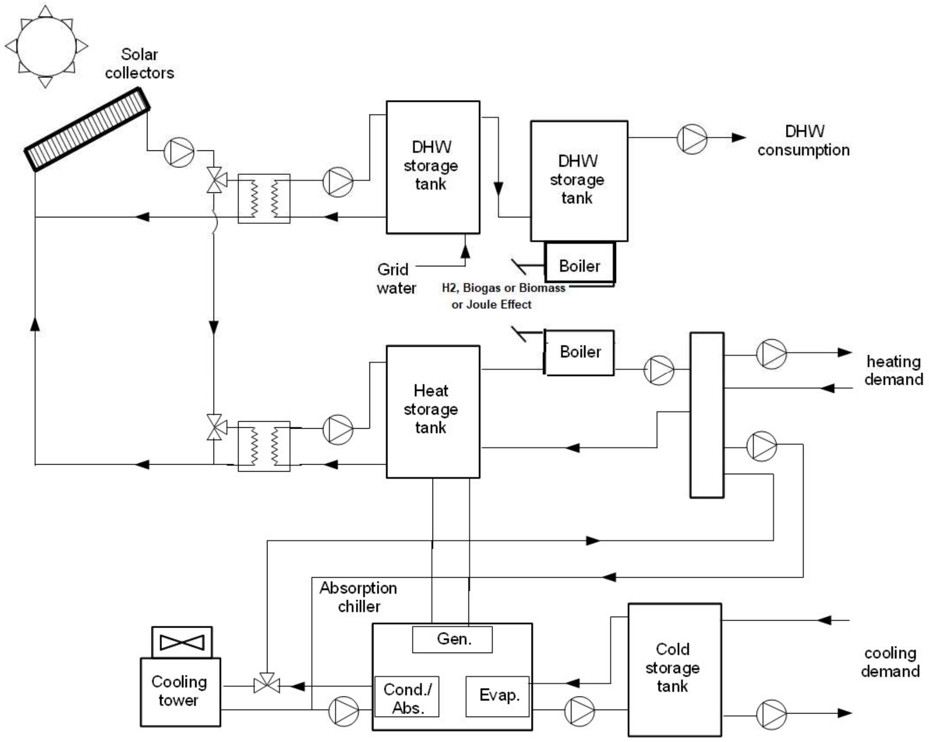

Fig. 5. Example of a Heating system with High fraction of Solar Thermal

2.3. Hotels with Combined Heat and Power.

The CHP systems have been installed in hotels the last 20 years, but they need a high thermal consumption and stable fossil fuel prices in order to be economically feasible. Due to the high variation of the fossil fuel prices, high cost maintenance and changes of grants in the electricity, a lot of these facilities have failed.

The renewable energy technologies could open a new market, being stable and more easy to maintain. Hotels with a high fraction of PV systems like the one proposed in the figure 4 could combine the thermal hotels proposed in the figure 5, using the hydrogen like a vector. At the heart of most Power-to-X concepts is the utilization of renewable excess electricity to produce hydrogen through the electrolysis of water. This hydrogen can be used directly as a final energy carrier. The fuel cell could help to provide 100% of the energy demand of a hotel, with higher efficiency than the Hydrogen produced in central plants, due to all the thermal exhaust of the hydrolyzer and the fuel cell could be used to supply the thermal necessities of the hotels and reduce the high energy consumption during the compression and the transport.

The big issue of Power-to-Hydrogen: converting electricity into hydrogen implies energy losses; Power-to-Hydrogen aims to achieve an emissions-free process by using renewable electricity in an electrolyzer to produce hydrogen from water. The main problem of the hydrogen produced with PV is the low efficiency of the whole process, less than 5%. However, using fuel cell in the main buildings could optimize the efficiency using the exhaust thermal from the fuel cell, recovering the heat and a total efficiency of nearly 10% could be reached by PV system. All the energy demand with a high efficiency could be provided with the help of the fuel cell, and that is the best storage for large periods. In the PV systems with Hydrogen we will need almost 4 times more surface than the Solar Thermal systems used directly for thermal uses, but as we have commented before, the storage and the management of the PV systems is easier, especially at Mediterranean tourist areas without District Heating systems. The gas sector could use in the future the existing pipeline as net metering systems for Hydrogen for Hotels like actually the Electric companies do. In this way will be easier to storage the excess of energy and avoid the collapse of the electrical systems, in a future scenario of 100% of renewable energies.

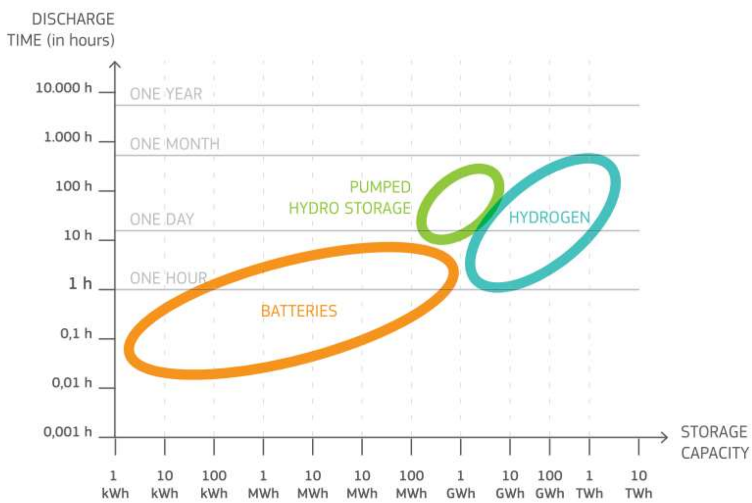

Fig. 6. Energy Storage. Source; Clean energy for EU islands, Technology solutions booklet

The suitability of storage technologies depends on the storage capacity required and the amount of time during which energy needs to be stored. The figure 6 shows only the three storage technologies that are included in the Clean energy for EU islands, Technology solutions booklet. The fuel cell has a great advantage that doesn't have mechanical parts and the maintenance is easier than the standard CHP systems.

The Hydrogen technologies will be studied with a deep analysis in the next years in the project Green hysland, where a Hotel with a commercial Fuel Cell of 50 kW as a demonstration site (as we can see at the figure 1 will be taken into consideration. The objective is to obtain the best solution in all the points of view; energetically, environmentally and economically, and find the optimal mix in each case.

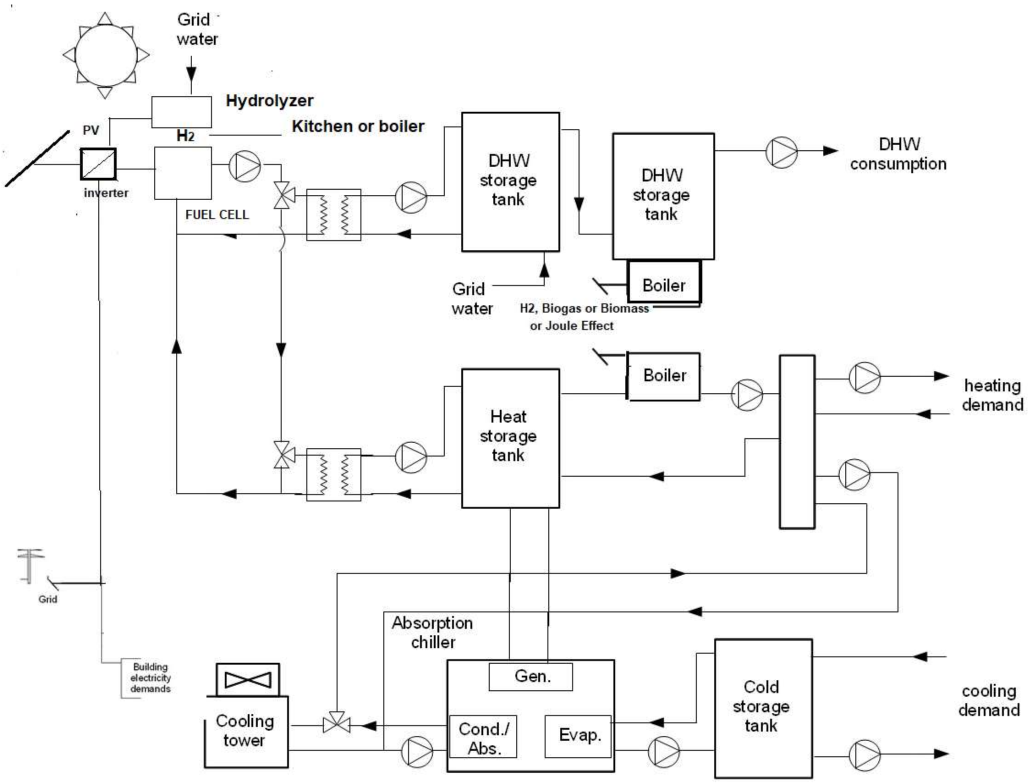

Fig. 7. Future Hydrogen Hotel

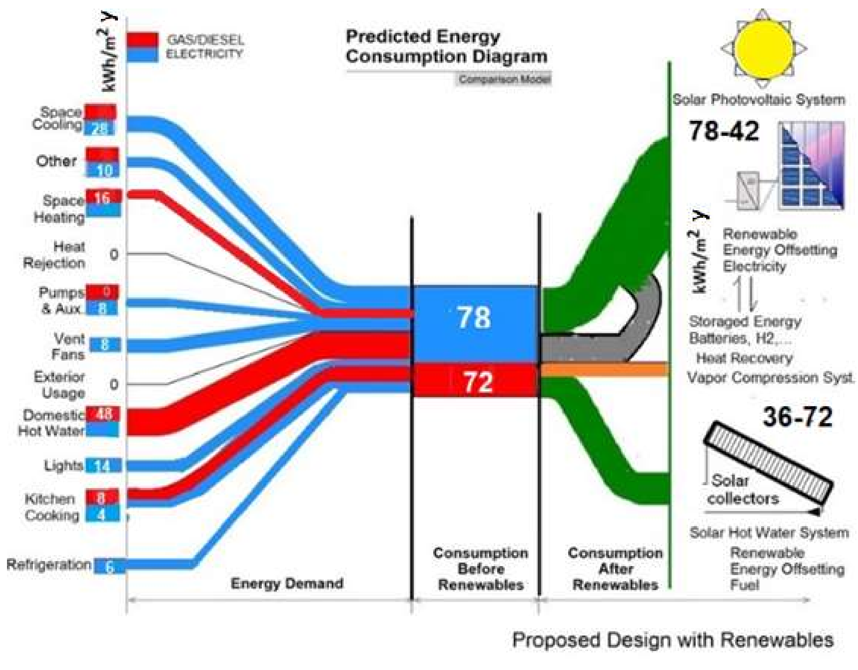

Fig. 8. Energy Sankey diagram in a average Hotel in kWh/m² year with 100% of solar energy

Actually in Majorca there are hotels which consume energy from 100% renewable sources (only with solar and biomass). The reduction of cost of some technologies (PV and Hydrogen technologies) could open other systems with 100% of solar energy. The hotels with only solar energy power will have to implement smart strategies, large thermal storage and small fraction with batteries or in other emerging technologies like Fuel Cell with Hydrogen(H_2) and Hydrolysis, in order to arrive to zero emissions systems, studied by Moià-Pol et alt. at 2020. Optimizing the energy mix of the hotels according to their demand and the available surface will be best scenario, using biomass or solar thermal with photovoltaics and small percentage of hydrogen in order to arrive to 100% of renewable energies. See at the table 2 some scenarios with renewable energies.

Tab. 2: Renewable mix for Hotels with different fraction

	ST	PV	W	Biomass	H_2	€/m² year
Hotel Biomass	0%	0%	0%	100%	0%	11,4
Hotel B-PV-W	0%	32%	6%	62%	0%	9,8
Hotel ST-PV-B-W	46%	30%	6%	18%	0%	7,7
Hotel PV-ST-B-W	14%	62%	8%	16%	0%	5,6
Hotel PV-ST	32%	68%	0%	0%	0%	5,6
Hotel PV-ST-W	16%	76%	8%	0%	3%	4,4
Hotel PV-W	0%	83%	17%	0%	7%	5,5

Another possible option in the future for Hotels will be for example, -to wait until the Electricity and the Gas will be produced 100% with renewable energies and use the standard technologies, but for this scenario we will have to wait more than 20 years that maybe the climate change will be irreversible. The big energy consumers like the Hotels need to be more active in the effort of decarbonizing the Islands. In the following table you can see how a future scenario could be that with the total number of Hotels in Majorca we could cover all the energy demand with the consumption of renewable energies.

Tab. 3: New scenario of the Majorcan Hotels with 100% solar energy. Source; Ibestat.caib.es

Category	Number	Beds	Electric Consumption (MWh/year)	Thermal consumption (MWh/year)	Category	Energy kWh/ m² year	Min. PV kWp/hotel	ST m² /hotel
5*	52	10981	18843	15417	5*	377	1047	256
4*	350	106221	74497	49665	4*	237	564	138
3*	200	51340	14360	7731	3*	158	175	33
2*	35	4583	2280	977	2*	120	148	23
1*	14	1069	848	212	1*	65	64	49
TOTAL	**651**	**174194**	**110828**	**74003**	**Average**	**191**	**400**	**100**

3. Conclusions

Applying new systems and Solar Energy to the hotels can result in a large economic and energetic saving and a reduction in CO_2 emissions without a significant change in client comfort by the increase of RES, especially the ST and PV systems. By changing from fossil fuels to solar energy sources (photovoltaic and solar thermal), we can arrive at zero or even positive building energy. In the future the Hydrolyzer with fuel cell will be 0able to integrate traditional heating systems of the Hotels and one can create a highly efficient system by operating with solar energy sources, based on fuel cell, solar collectors and photovoltaic elements for zero energy Hotels with low electrical storage and reasonable thermal storage.

4. Acknowledgments

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5. References

A Moià, B. Rosselló-Batle, Pujol R., V. Martínez. Net zero energy in hotels and touristic areas in the Balearic Islands. Eurosun 2010.

Andreu Moià-Pol, Miquel Alomar Barceló, Ramon Pujol Nadal, Víctor Martínez Moll. Domestic solar/heat pump heating systems with low and high efficiency collectors in Mediterranean areas. Proceedings of the Solar World Congress 2011, Kassel, Germany

Vassiliki N. Drosou.Panagiotis D. Tsekouras , Th.I. Oikonomou, Panos I. Kosmopoulos, Constantine S. Karytsas. The HIGH-COMBI project: High solar fraction heating and cooling systems with combination of innovative components and methods. Renewable and Sustainable Energy Reviews 29 (2014) 463–472

A. Moià-Pol, P. Rullan, B. Alorda. Intelligent Thermal Storage in the Balearic Islands Hotels. Workshop proceedings of Intelligent Environments and Buildings. IEB'20.(2020) Madrid, Spain 252-258

https://greenhysland.eu/ Grant Agreement No 101007201.

Clean energy for EU islands. Technology solutions booklet. EU publications. ISBN 978-92-76-41545-9

Statistic Department of Balearic Government https://ibestat.caib.es/

Esther González Arnedo, Jesús Alberto Valero-Matas and Antonio Sánchez-Bayón. Spanish Tourist Sector Sustainability: Recovery Plan, Green Jobs and Wellbeing Opportunity. Sustainability 2021, 13(20), 11447; https://doi.org/10.3390/su132011447