From Diesel to Eletric to NZEB, an Energy Performance Contract in a Hotel

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Abstract.
How could a 1975 4* 220# bedroom beach hotel evolve from an old system with Diesel Boiler and cooling only chiller to become a NZEB building. An Energy Performance Contract, funded by Innovation funds, an hotel in south Portugal obtained 60% Energy reduction, a new Chiller and integrated Heat Recoveries results on eliminating diesel consumption with almost free Sanitary Hot Water in the summer and next steps to achieve a NZEB Building. Energy Performance Certificate came from D to B which is already considered NZEB in Portugal.

Keywords: Energy efficiency, Energy Performance Contract, Heat Recovery, ESCO, NZEB, Hotel, BMS
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1. Introduction

From first Energy Audit to implementation commissioning, post-work improvements, installation conduction, energy management and maintenance management a story on how an old idyllic 220-bedroom hotel by the beach can become a modern NZEB building. This is the PESTANA VIKING RESORT in *Sra. Da Rocha* beach, near Porches, Algarve, PortugalLessons learned and what remains to be done

2. Methodology

2.1. Motivation and procedure

In 2013 *"FAI-Fundo de Apoio à Inovação"* (Innovation support Fund in Portugal) launched a national challenge for Energy Performance Contracts in Portuguese Hotels.

Main objectives were to promote awareness of this business model as an effective way to achieve Energy Efficiency so needed in this Industry and in Portugal in general.

In a first stage several hotels concurred and the one with most expected savings was selected.

Savings were diagnosed via an Energy Audit included in the Energy Performance Certificate according to the EPBD Directive. This hotel was was the one with more potential savings.

In a second stage several ESCO companies applied to implement the Energy Efficiency Contract. Among 9 companies that presented a proposal the best two were pre-selected and allowed to run a final Energy Audit and present a final proposal.

The same candidate had the first place in both situations. The prize consisted of financing the investment needed without interests with one year of payment absence to allow implementation and three years of monthly payments according to a M&V report.

This loan was secured by a bank first demand guarantee.

The juridic discussion to reach an agreement between FAI and the Bank (which is also state owned) took over 8 months.

The final contract between the ESCO company and the Hotel is five years long despite paying the loan in three years

2.2. Existing situation

The Viking Hotel met particularly advantageous conditions for reduction of Energy Costs. It is a building from the 70's, it did functional and cosmetic renovations over the years, but maintaining most of the original Air Conditioning Systems.

A major renovation in 2005/2006 created an indoor pool with a dehumidifying machine, but pool heating was made still with boilers.

The construction is entirely in concrete, there are no bricks, only concrete and glass, which makes it thermically inefficient and very dependent on active air conditioning to maintain the comfort of customers.

An original cold water/water chiller with cooling tower produces the hotel comfort cooling.

Existing Chiller had EER~1

Fig. 1- Old Chiller and Cooling Tower

Chiller circulating pumps were fixed speed.Fan-coils and AHUs had three-way valves with no hydraulic balancing.

Two diesel boilers produced all the Ambient Heating in winter and all the SHW- Sanitary Hot Water and all Pool Heating during all the year.

Heating Diesel in Portugal is almost at the price of Road Diesel, making it an expensive energy.

2.3. Energy Audit

A thorough Investment Grade Energy Audit was carried out under the mandatory Energy Performance Certificate for this application.

A detailed Thermal Simulation of the building was carried out making a 3D model in REVIT exported to IES/VE thermal simulation Software.

A high degree of calibration of the building was achieved, allowing for an accurate study of improvement measures and simulation if interaction between measures.

The response of future Air Conditioning equipment was studied in detail by calculating an EER-Energy Efficiency Ratio and COP-Coeficient of Performance for all hours of the year for various reversible chillers considering the thermal load required in each hour obtained from the building thermal simulation and the Average Outside Temperature for that hour obtained from an average statistic of last three years.

This study allowed to approach specific SEER-Seasonal EER and SCOP- Seasonal COP of this Building for each chiller analysed which led to a more fundamented decision.

The building consumed 1.4 MWh in Electricity and 1.1 MWh in Diesel per year in which HVAC-Heating, Ventilation and Air Conditioning including SHW accounted for about 42% and Illumination about 19%.

The analysis of hydraulic schematics of existing installation showed something very old and obsolete, in view of new technologies and new ways of connecting equipment.

Realizing how the facility worked by listening to the maintenance people who knew how to operate, problems and complaints of the various users, such as the Kitchen, Restaurant, Reception, Rooms, and Swimming Pools were very important to know the current state and think about the future.

A big problem created in the 2005 remodulation were ten Condensing Refrigeration groups from the freezing and cooling modules located in a closed basement with minimal mechanical ventilation and an AHU-Air Handling Unit cooling the technical room in summer when chiller was on. That space overheated frequently creating breakdowns on the refrigerating machines

Fig. 2- Refrigerating Condensers

2.4. Results of Energy Audit

Disaggregation of consumptions are below

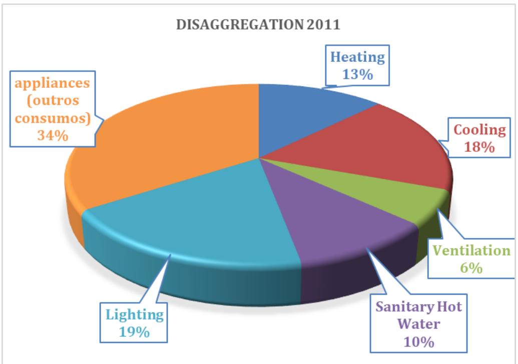

Fig. 3- Energy disaggregation 2011

Wall thermal insulation and Windows replacing would result in many years of Return On investment. Most Promising Energy Conservation Measures are about remodelling hvac system and lighting

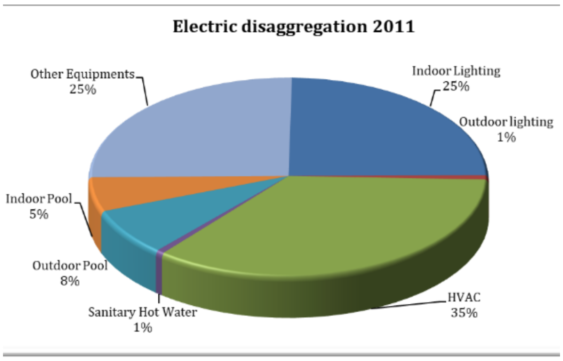

Fig. 4- Eletric Consumption disaggregation

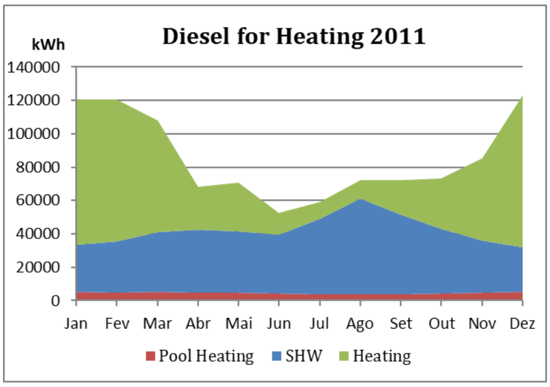

Fig. 5- Diesel Monthly consumption

3. Measurement & Verification Plan

The path between EIM-Energy Improvement Measures stated in a report, how to really obtain them and how to invoice them is an iterative road, with both financial, hvac engineering, statistical and juridic discussion of work and contract.

Each time we go to the building we discover new things and get deeper insights until we format the final solution

A M&V – Measurement & Verification Plan was developed according to EVO IPMVP protocol Option C. [1]

This option includes overall building consumptions and is based on the actual Electricity and Diesel invoices paid by the Hotel.

Baselines formulas were provided for Electricity and Diesel consumptions. After dozens of tests, we agreed with the client on the formulas below obtained wit statistical regression methods made in advanced Excel.

according to IPMVP protocol an accordance of at least 75% should be obtained as enough precision to make it agreeable between both parties. Above 90% the dependency of the Y variable is very well explained by the independent variables.

The data set used was the latest 24 months, including monthly real occupation of hotel, real historic consumptions and daily temperatures obtained by the nearest official weather station, as no historical temperatures measurements existed at the hotel.

This was a laborious and iterative investigation process till find options both could agree on.

Baseline Eletricity

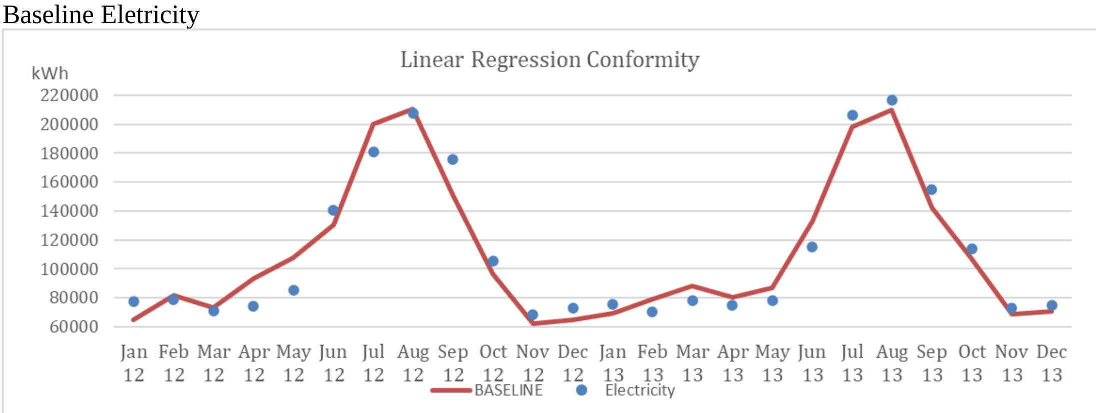

Fig. 6 – deviation between data and Electricity Baseline

$E = a + b\ NC + c\ DDheating + d\ DDcooling$

Where:

E= monthly Electricity kWh	DDheating = Heating monthly Degree Days in base 18ºC
NC = Number of monthly clients	DDcooling = Cooling monthly Degree Days in base 24ºC
a,b,c are constants	$R^2 = 94.4\%$

Baseline diesel

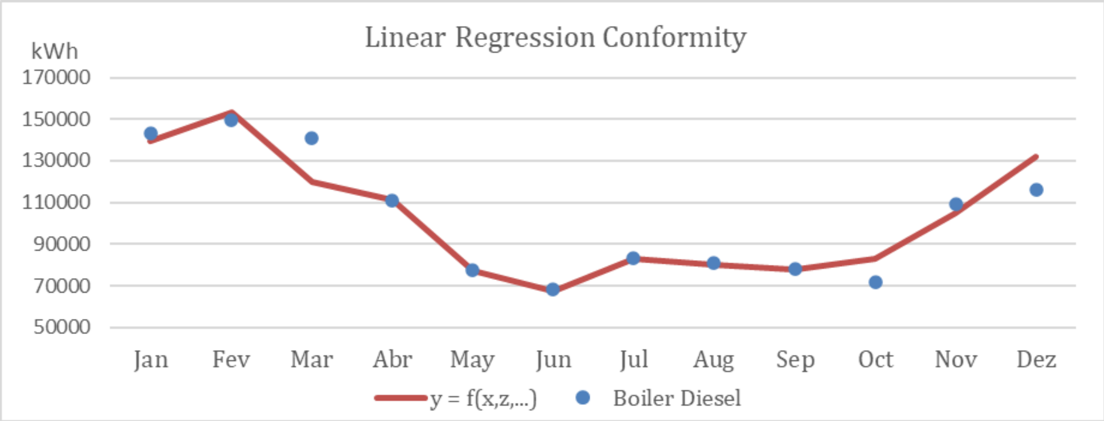

Fig. 7 – deviation between real data and baseline Diesel

$F = d + e\,NC + f\,DDheating - g\,Texternal$

Monthly data used is an average of 2012 and 2013, a typified year for 24 months

L= monthly diesel kWh	DDheating = Heating monthly Degree Days in base 18ºC
NC = Number of monthly clients	Texternal = average outdoor monthly temperature
d,e,f,g are constants	$R^2 = 91.2\%$

Please notice the negative ***"g"*** coefficient on diesel expression, as diesel was all year long for SHW production and winter heating.

4. Initially Implemented measures

The call was released 2013, implementation only started in2016 due to a lot of legal contracting delays.

Main works were done in spring of 2016, including new chiller and boiler remodulation

The hotel closed for other renovations from November 2016 to February 2017, allowing for works inside rooms to be done without constraints.

Fig. 8 – New Reversible 2 pipe Chiller 300 kW cooling

The great revolution consists of altering the Centralized Hydraulic schematics. We now have a chiller with Variable Speed in the Primary Circuit, Partial Heat Recovery at high temperature using desuperheater with high Delta T on the heat recovery water. Heat production in counter current with the consumption of SHW and an auxiliary Heat Pump.

Installation of a Reversible Chiller produces all Cooling, Heating and most of the need for Sanitary Hot Water. We chose the one that had the best Values of EER and COP in Eurovent and in our study, but also the one that could achieve the desired Heat Recovery values.

Fig. 9 – Heat Pump recovering heat from refrigeration Condensers and producing SHW, 15kW thermal at 60ºC.

Building Management system was designed in partnership between a BMS contractor and the ESCO company became the only way to commission and explore the entire installation automatically to obtain the best results, controlling the entire thermal power plant and AHU-Air Handling Units.

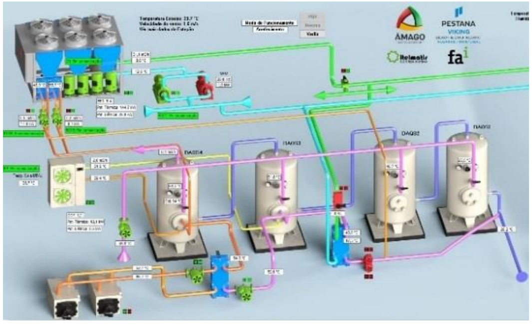

Fig. 10 – BMS synoptics

It took roughly one year to optimize the BMS system, we had to see it working and tweak it one winter and one summer to achieve the desired results

BMS works together with an Energy Monitoring System producing automatic alarms detecting early anomalies and inefficiencies as a complement to daily remote visits to the system by an engineer that makes a close installation follow up, daily decisions on setpoint temperatures, etc.

Review of all energy-consuming equipment connected to HVAC, Swimming Pools and Kitchen considering the daily control and operation trying to improve some energy-saving behaviours.

Recommissioning has been done for the AHUs and Pool dehumidifier, measuring air and water flows on the machines and balancing Air diffusers.

Pressure Independent Control Valves for AHUs and room's Fan Coils, combined with Variable Speed Circulation Pumps have been installed. This guaranteed proper balance of hydraulic circuits.

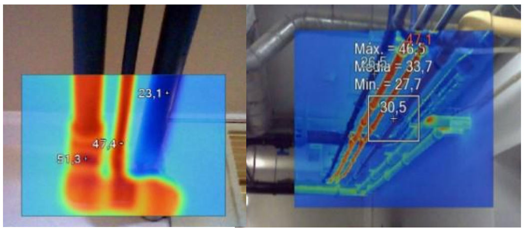

Fig. 11 – Infrared thermography on SHW pipes

Low flow showers were installed

As original condition had many flaws, thermal insulation of the entire distribution network of Sanitary Hot Water and Recirculation with 30mm thickness insulation was applied, which is operating 24hours/day and responsible for 12 to 15 kW of constant heat losses on the building. Even with proper insulation Sanitary Hot Water pipes accounts for 20% to 30% of total heat necessary for Hot Water. There is still room for a lot of improvement here.

Installation of a hot water disinfection system by Chlorine Dioxide to avoid frequent thermal shocks and reduce or nullify the risk of Legionella; This system proved effective on disinfection but also very corrosive for all kinds of plastic piping, accessories in brass and bronze. It was decommissioned late 2018 due to piping bursts.

Illumination retrofit for LED lamps was already ongoing by hotel Maintenance, including bedrooms, except service areas, so all Tubular Fluorescent lamps were replaced in common and service areas, like kitchen, reception, corridors, technical rooms, etc.

4.1. Commissioning and First Results

Commissioning and optimizing the new installation are an ongoing process since months since February 2017 till the end of 2018

Results improved a lot since early 2017, but still spending too much diesel till June 2017, as the objective is to have zero diesel consumption

Till July of 2017 diesel consumption remain high due to:

- Compressor in Dehumidifier was burned, and all pool heating was provided from the boiler;
- Condensing Heat from the chiller was not being properly recovered due to lack of stability on circulating pumps, controls need improvement.
- These problems were solved during 2017 leading to much better results and achieving the proposed goals
- Other improvements opportunities were detected meanwhile.

4.2. After commissioning investments

Indoor Pool Air Treatment Dehumidifier Ventilator was a centrifugal belt driven with 5.5 kW electric motor replaced by an EC plug fan of

2.2kW running at half speed at night time with 0.8kW power.

Around 2k€ Investment for 1k€/year energy savings, two years Return on Investment, we still had four years to go, so was a easy decision.

Fig. 12 – Old belt Ventilator and new EC Fan

Also, the Extraction Fan for the main Hood in the Kitchen needed replaced for Fire Safety purposes, we analysed the possibilities and replaced an old 4 kW centrifugal and belt ventilator, for a direct coupling plug fan 400ºC/2h ventilator

Fig. 13 – New Kitchen Fan

Heat Recovery form the two large refrigerating condensers was made directly to heat Indoor Pool Water through an Heat Exchanger, which accounted for almost all pool water heating needs in summer and dismissing other need for the boiler.

An hydromassage tub exists on the Indoor Pool space and was heated by electric immersion heaters. A Pool heating Heat Pump was installed inside the kitchen providing cooling for the kitchen and simultaneously heating the tub. small 9m2 room is used as a refrigerated wine cellar including two refrigerators for soft drinks and white wines while red wines were left at room temperature. An Air Conditioning split type Unit worked inside to cool the premisses. We were able to remove the condensers for the room and install another small heat pump producing SHW while cooling the wines. In this way both sides of the compressor are useful, cooling and heating.

5. Results for 2018 and 2019

All the implemented measures resulted on a highly efficient operation.

The graphs in Fig. 13 to Fig.16 allow several conclusions:

- Peak Electricity consumptions on summer due to high cooling needs remain, but are now at much lower level
- There is no Diesel utilization in summer and mid seasons, therefore all Sanitary Hot Water and Pool heating is being made with Chiller, Heat Recovery and Heat Pumps.
- Electrical consumption in Winter, from December to February, is almost the same as it was before, but with no Diesel spending, meaning other ECM-Energy Conservation Measures were able to reduce electricity use in Winter, like lighting, ventilation fans and better control on climatization by BMS
- A Photovoltaic system would be the ideal complement to this building, has almost all use is electric energy. The conditions on the call were not interesting for Photovoltaic, so it as not integrated on the first investment.
- Most Energy Consumption is about appliances, not traditional hvac, lighting and other regulated uses.

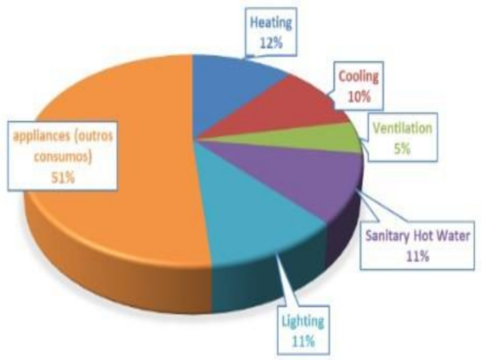

Fig. 14 Energy Disaggregation 2019

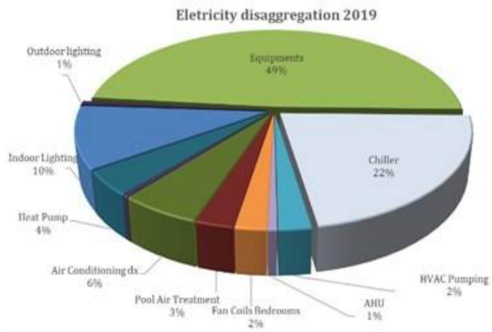

Fig. 15 Electricity Disaggregation 2019

In March 2020 a general lockdown was declared in Portugal as most of Europe and the World. Hotel opened only from 06/07/2020 till 12/09/2020 and reopened in July 2021 to close again in September 2021. No more full years of operation are available.

No further investments were made

As life is expected to normalize in 2022 so will hotel exploration and investments.

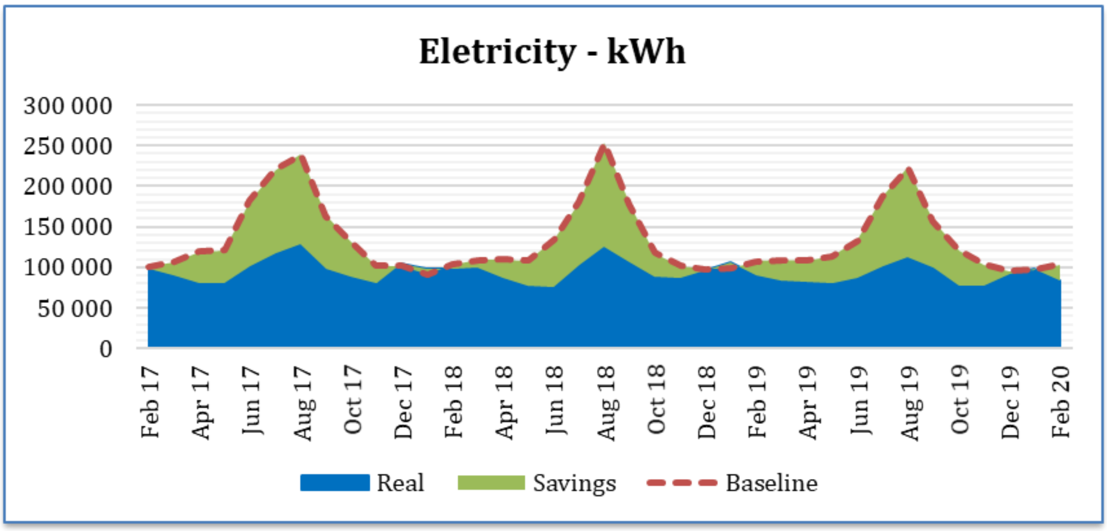

Fig. 16 – Electricity savings between Feb 2017 and Feb2020

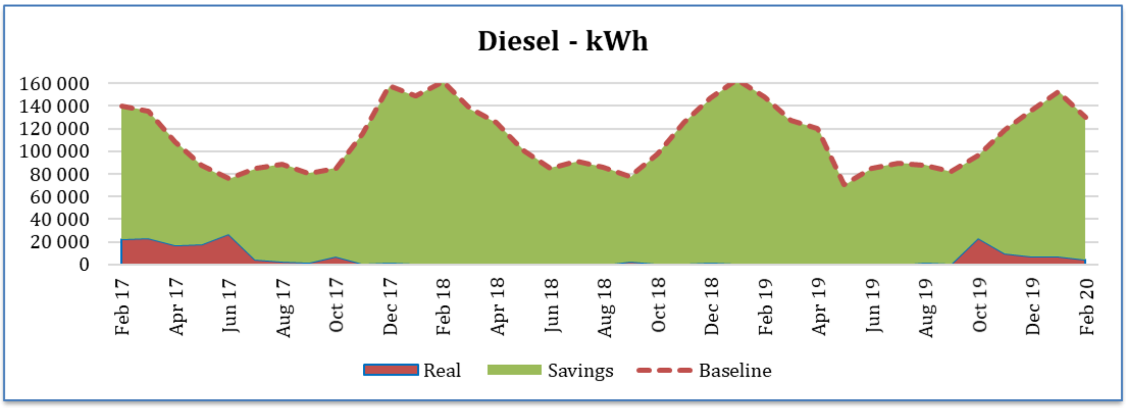

Fig. 17 – diesel savings from Feb2017 to Feb2020

The Diesel used in October 2019 was due to a Heat Pump malfunction

6. Conclusions and steps to NZEB

According to Portuguese Energy Performance Certificates for 2021, this building is already considered to NZEB, as it reaches Class B minimum on 2021 classification for commercial and Service Buildings

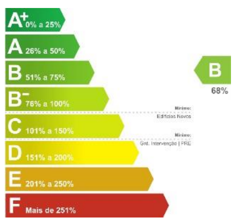

Fig. 18 – Energy Rating in Portugal in 2021

But the REHVA definition of a NZEB building [2], [3], [4] has a wider scope, and in a very short version can be defined as the balance between imported and exported energy throughout an year tending to zero, reducing internal consumptions, complementing with self-consumption renewables, a building could sell energy some hours of the day and buy at other hours.

Table 1 resumes energy consumption on three phases of the building being able to achieve NZEB status since 2011, on 2019 and with future implementation of a PV system.

More work will be done to improve the building exploring new improvements. Reducing electric consumption on kitchen, restaurant, bar appliances and bedrooms, will be of utmost importance. Adhering the final client to this sustainability challenge is another task, involving him on saving energy water, residues, laundry, etc.

Available space in roofs allow a Photovoltaic installation of 120kWp with an expected yearly production of 243 MWh allowing hotel to become a NZEB building.

Example of measures to study are [5]:

- Heat Recovery from refrigerating condensers
- EC fans on refrigeration devices
- Advanced Room Management to reduce equipment, lighting and hvac consumptions with and without client presence.
- Occupancy detection on corridor lightings
- Fan Coils with EC fan motors
- Develop a energy monitoring plan allowing early detection of deviations
- Hydric efficiency, with low flow lavatories and toilets
- Thermal insulation on walls. Walls are concrete, applying ETICS would result on greater comfort. ROI is above 50 years, but with incentive financing would be viable.
- Window replacing from single pane to double pane. ROI is more than 50 years, but with expected financing would be viable
- Replacing old AHUs with new EC fan motors and Heat Recovery.
- Make achieving energy goals part of staff evaluation and bonus

Tab. 1 – Hotel Evolution from inefficient to ZEB

			Class B	Class A
		2 011	2 019	2 023
	Class	**C**	**B**	**A**
Specific Energy	$kWh_{EP}/m^2/year$	295	198	157
	kWh_{EP}/room	114	51	41
	kWh_{EP}/client	50	23	18
CO2	Ton/year	753	430	342
Total Energy use	kWh_{EP}/year	4 395 149	2 952 579	2 952 579
Delivered Energy	kWh	4 395 149	2 952 579	2 343 082
Exported Energy	kWh	0	0	0
Self-Renewables	kWh	0	0	243 799
Disaggregation	$kWh_{EP}/m^2/year$			
Heating		37	23	23
Cooling		53	21	21
Ventilation		18	10	10
Sanitary Hot Water		30	21	21
Lighting		56	21	21
appliances		101	102	102

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