TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

DIPLOMARBEIT

Energy Efficiency Potential of Luxury Housing in the Valley of Mexico

unter der Leitung von

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von

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I cherish my parents and sisters for their solid support over the years. Thanks to my family members and friends who have always shown their unconditional affection.

This work would not have been possible without the Matouk and Hernandez family. I value the involvement of the following people: Dir. Ana Maria Carranza, Dipl. Controller Nicole Wiegele, Engr. Jesus Arrieta, Prof. Cristina Camacho, Engr. Teodoro Cesta, Arch. Kristian Arciniega, Dipl. Joel Quesada and Engr. Israel Gutierrez. Their contribution is deeply appreciated.

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Este trabajo no hubiese sido posible sin la colaboración de las familias Hernández y Matouk. Valoro el involucramiento de las siguientes personas: Dir. Ana María Carranza, Lic. Nicole Wiegele, Ing. Jesús Arrieta, Lic. Cristina Camacho, Ing. Teodoro Cesta, Arq. Kristian Arciniega, Lic. Joel Quesada y el Ing. Israel Gutiérrez. Su contribución es profundamente apreciada.

ZUSAMMENFASSUNG

Diese Arbeit konzentriert sich auf die Energieeffizienz von Luxus Häusern im Valley von Mexiko ("VOM"). Ziel ist es, den Energieverbrauch in einigen der so genannten besten Wohngegenden in der Hauptstadt (West und Süd) zu analysieren, der Grund zur Auswahl von Luxus Häusern liegt darin, dass diese der "Kategorie der DAC" (spanische Bezeichnung für Residenzen mit hohem Energieverbrauch) entsprechen. Jede Residenz, deren Verbrauch die 500 kWh Strom in einem Bimester übersteigt, fällt in die "Kategorie der DAC". Die "VOM"-Region hat die höchsten Energiekosten des Landes. Bis dato konzentriert sich der mexikanische Solarmarkt für den Wohnbereich auf einen Wettbewerb mit dem "DAC"-Tarif , da es bei diesem keinerlei staatliche Subventionen gibt, dieser Umstand macht die Technologie sehr wettbewerbsfähig. Benutzer mit einem geringen Energieverbrauch unter der "Kategorie der DAC" genießen niedrigere Energiepreise und erhalten staatliche Subventionen. Das Valley von Mexiko ist die Heimat von etwa 21 Millionen Menschen (davon leben fast 9 Millionen in der Hauptstadt). Der Mangel an Energie Normen sowie an Umwelt Bauvorschriften ist ein wichtiges Thema, mit dem sich diese Abhandlung befassen wird. Wie viel Energie können wir bei Luxus Wohnprojekten im Valley von Mexiko sparen? Wie kann das umgesetzt werden? Die finanzielle Machbarkeit in Zusammenhang mit den jeweiligen Amortisationszeiten wird ein integraler Bestandteil der Analyse sein. Welche Design-Strategien sollten im Auge behalten werden? Könnte diese Studie als Beispiel für strengere Normen im Energiebereich herangezogen werden? Die mitgelieferten Daten werden notwendige Änderungen in Design, Material und Ausrüstung aufzeigen. Das Ziel dieser Abhandlung ist es, potenzielle Vorteile von Energieoptimierungsstrategien aufzuzeigen, die Verwendung von EPS tools zu fördern und einen Vorschlag für geeignete Energie Normen herauszuarbeiten.

ABSTRACT

This thesis focuses on energy efficiency in luxury housing in the Valley of Mexico. The objective is to analyze energy performance in some of the most exclusive residential areas in the capital (West and South). The reason luxury housing is selected is due to its category of DAC (High Consumption Residential). Any residence that exceeds 500 kWh of electricity consumption in one bimester falls in the DAC category. The VOM region has the highest energy bills of the country. Until recently, the Mexican solar market was focused on competing with DAC tariff for the residential sector since it has no government subsidies and makes the technology highly competitive. Users with low energy consumption under DAC category enjoy lower energy prices and government subsidies. The Valley of Mexico is home to approximately 21 million people, (almost 9 million belong to the capital). The lack of energy standards and environmental building codes is a major matter of concern to address in this thesis. How much energy could we save in luxury residential projects in the Valley of Mexico? How exactly can it be done? The financial feasibility will be an integral part of the analysis along with the respective payback times. What design strategies should be kept in mind? Could this study serve as an example for stricter energy standards? The data reports provided will suggest necessary modifications in design, materials, and equipment. These thesis targets are to exhibit the potential benefits of energy optimization strategies, to encourage the use of EPS tools and consolidate proper housing energy standards.

Keywords

Optimization, Energy consumption, Savings, Development, Standards, EPS tools

To all the forces that have aided me in my life.

CONTENTS

1 INTRODUCTION

1.1 Overview

Each state in the country has its own building codes. However all are really behind in terms of energy optimization. Since 2007 Mexican law grants any user whether it's residential or commercial, the right to generate its own electricity with solar means interconnecting to the grid. It is permitted to generate a maximum of 10 kW per day. There is still a long way to go.

Since 2008 in Austria Energy Performance Certificate is required for buildings at: sale, renting and leasing. This mandatory energy regulation is practically non-existent in Mexico. There's a clear tendency of pursuing the way of LEED certification for example, but rather as a reward than as a must for improving the environment.

In addition most of the EPS tools used in Austria, Germany and the US are not of common use in Mexico since it is perceived as unnecessary, it is work considered as a plus. Instead, one of the biggest concerns is to comply with seismic protection requirements.

Mexico City and its metropolitan area are doing well in terms of environmental policies. Although air quality still leaves a lot to be desired, the government air quality programs have decreased CO_2 emissions since the 1990s by 40% and have implemented a great variety of public transportation systems. Green roofs and vertical gardens have skyrocketed —so as the real estate— with a clear goal of covering 40% of the city by 2030.

The Valley of Mexico is the main economic engine of the country; it represents 25% of the GDP. No doubt it is the settlement that leads the country, and is the role model for other states.

1.2 Motivation

The government could use examples in order to regulate and improve building codes. Examples that come from design, plan and execution of environmental strategies. If proven what EPS tools can do, what solar technology can provide, the amount of energy that can be saved and how their implementation is in fact is an ideal situation for everybody involved in the process, a new building model will spread throughout the country.

1.3 Background

1.3.1 Overview

It is important to address that Mexico has one of the highest electricity tariffs in the world, one of the most expensive kWh/$ rates. This is quite remarkable when considering that the country has more than 50 million people living in poverty (42% of the population) and vast energy resources.

The rising pricing of services (water, gas, and electricity) has increased the awareness for such resources.

Currently there are only a few solar technology companies in Mexico. One of the major obstacles is cultural since there is a part of skepticism and restraint regarding investments in solar equipment and innovative energy efficient equipment.

The thesis will rely on the analysis of 2 residences. One is under construction but because of recession its construction has been paused several times; the other one was built in 1980 but it will be completely renovated, starting beginning of 2014. The analysis results along with the financial study will suggest the necessary improvements in energy performance.

The objective of this research is to assess how and to what extent energy can be optimized in residential buildings in the Valley of Mexico.

1.3.2 Global Context

Our global economy is outgrowing the capacity of the earth to support it, moving our early civilization even closer to decline and possible collapse.

The world is being affected by the current state of our natural resources including the oil peak, water shortages, global warming and its effect on sea levels, shrinking forests, growing deserts, and extinction of plant and animal life.

Social issues, such as failing health and poverty are affecting the future sustainability of our environment. It is not certain whether the alternatives currently developed slow down or even bring to a halt any more harm to our environment.

In the global arena, Mexico is one of the top oil and natural gas producers in the world. However it is facing difficulties with decreasing oil reserves, lack of environmental policies and investments.

CFE and PEMEX, dominate the electricity and oil and gas sectors respectively. CFE currently holds a monopoly on electricity transmission and distribution. The fact that there is only 1 electricity company in the country, gives CFE absolute control on the service and tariffs.

This is reflected as Mexico's electricity prices are among the highest in the world. Especially considering their purchasing power.

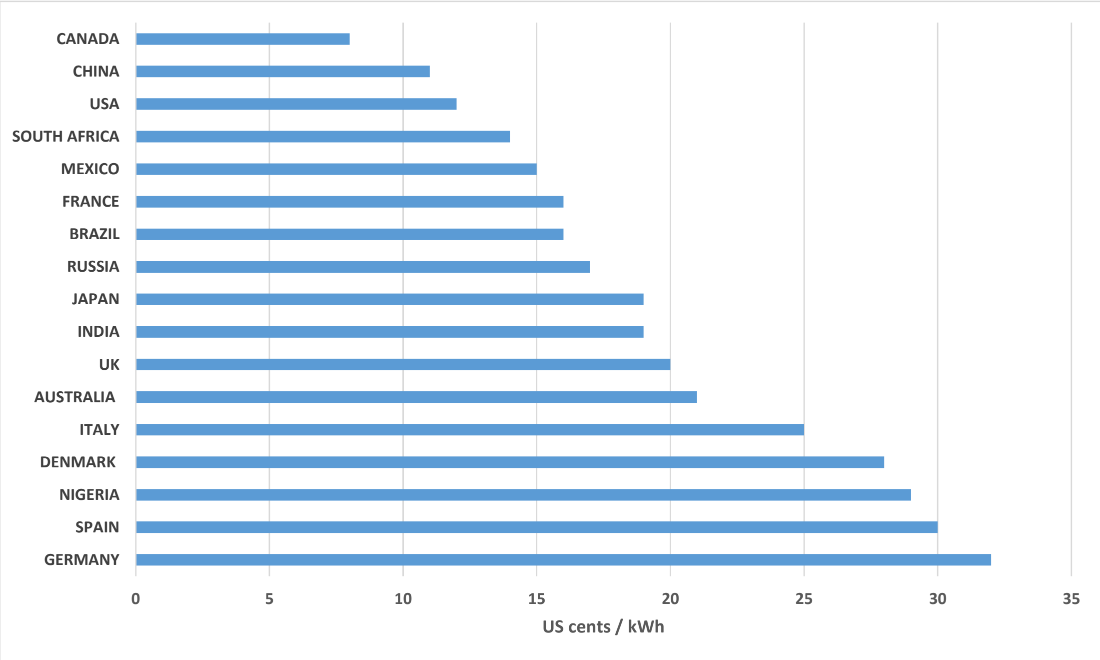


Figure 1. World electricity prices relative to purchasing power (IEA).

Mexico is Latin America's largest fossil fuel-consuming country. The majority of the country's greenhouse gas emissions come from energy production and consumption. The country has great potential in terms of solar energy (70% of the territory has GHI values of 4.5 kWh/m2) but it is far behind even compared to countries with much less solar radiation.

Mexico has 40% more solar radiation than Austria. In spite of this, Austria has 245 m2 of solar panels per 1000 inhabitants while Mexico has an amount of 0.33 m2 of solar panels per 1000 inhabitants.

The following image from NASA shows Global Solar Radiation, as seen, Mexico is one of the countries that stands out with a significant amount of Solar Radiation.

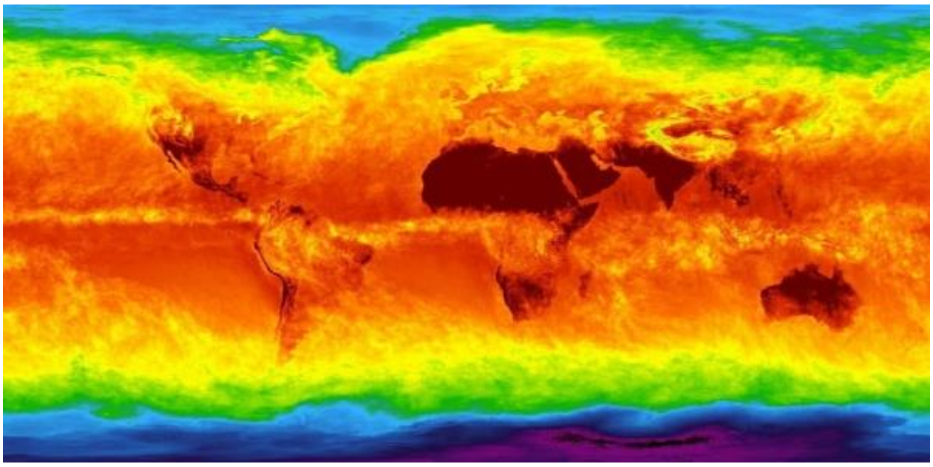


Figure 2. Global solar radiation map (NASA).

Today, solar power in Mexico amounts to less than 1 percent of Mexico's total energy production, meaning solar power is not only in its primary phase, it is a huge opportunity.

1.3.3 Energy in Mexico

Despite its huge solar potential, Mexico remains seriously underdeveloped in terms of solar energy. Until recently, Mexico's solar industry has focused on small, off-grid photovoltaic (PV) installations in remote areas to supply the over 3 percent of rural Mexicans who are not currently connected to the grid. But entry into the Mexican solar industry market has specific obstacles. Mexican utilities are state-owned, making it difficult for independent power providers to enter the Mexican market which includes power generation, transmission and distribution controlled by the government's Federal Commission of Electricity (CFE). This means any development of the solar industry requires government backing.

The Constitution reserves power supply and distribution as an exclusive right of the State (except for self-generation for less than 20 MW capacities).

However, it is legally allowed to have an interconnected system with solar PVs. This interconnected systems are quite useful especially in the High-Consumption electricity tariffs.

1.3.4 Mexican Electricity Sector

The electricity sector in Mexico relies heavily on thermal sources as seen on Figure 3 (66% of total installed capacity), followed by hydropower generation (22% of total installed capacity). Although exploitation of solar, wind, and biomass resources has great potential, geothermal energy is the only renewable source (excluding hydropower) with a significant contribution (2% of total installed capacity) to the energy mix.

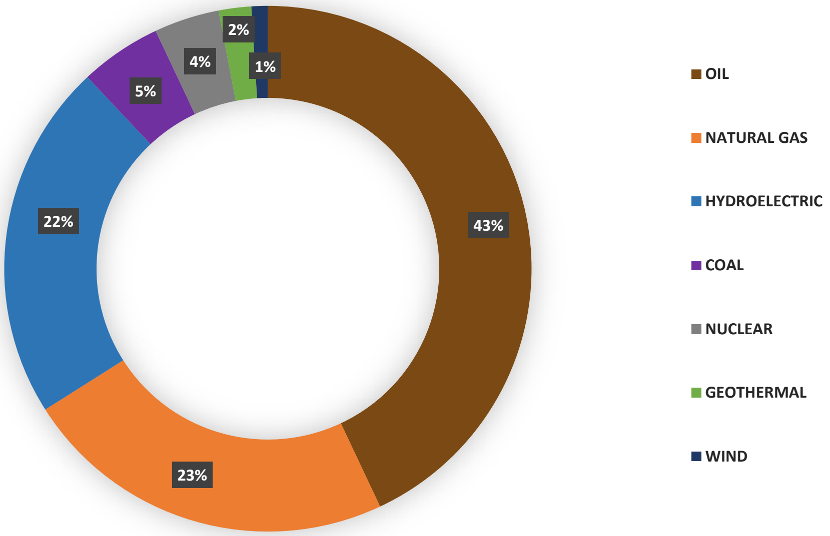


Figure 3. Mexico electricity generation (SENER).

According to statistics from CFE, over 97% of Mexico's population has access to electricity. About 99.5% of the electricity generated by the CFE is for domestic consumption, and the remaining 0.5% is exported. As of July, 2013, 88.5% of domestic consumption was for residential use.

Electricity demand is rapidly growing (over 4% since 1995). Over half of industrial energy use takes place in the cement, iron, steel and chemicals and petrochemicals industries.

Air conditioning, refrigeration, and electronics are expected to be the main growth areas of residential electricity demand and thus are prominently featured in the low-carbon interventions in the sector.

1.3.5 Policies

Stabilizing the climate and using alternate forms of energy can be done on a national level, but it also comes down to the individual consumer. Choosing public transport or eco-friendly transportation, hybrid vehicles, low-wattage light bulbs, and energy efficient appliances can make a large impact on the energy shortage. The government can also influence the purchase of these products through incentives such as tax write-offs or rebates. Other energy alternatives should be explored.

The current system is not accurate on all aspects, and it does not take nature and our environment into account. Expanding renewable energy and energy efficiency in the power sector would require several policy and regulatory changes.

Policies to improve efficiency in the residential, commercial, and public sectors—including tightening and enforcing efficiency standards for lighting, air conditioning, refrigeration, and buildings—will be critical to limit future GHG emissions.

Examples of important policies for energy efficient development include

- Electric Power—reforming energy prices, specifically residential electricity tariffs and increasing the price of petroleum products (gasoline, diesel, LPG, fuel oil) and natural gas.
- Tax benefits—

According to article 32 fraction XXVI of the ISR Law, taxpayers who invest in machinery and equipment for power generation from renewable resources may deduct 100% of the investment.

Homeowners or real estate for residential use owners who install and use devices such as solar panels and systems for collecting rainwater for decreasing energy consumption and / or water or recycling of the latter, may obtain a reduction of up to 20% of the water rights. The reductions referred to in this Article shall apply in accordance with Article 297 of this Code.

1.4 Weather data

The weather data presented, shows the meteorological context of the Valley of Mexico. Some of the following climate data (yearly temperatures, diffuse and global radiation) demonstrate the temperate climate of the VOM, due mostly to its high elevation (minimum altitude of 2,200 m above sea level) as well as its abundant solar radiation conditions. Both projects are located in the least warm regions of the valley (West and South).

Figure 4 to Figure 6 present the Valley of Mexico's typical weather conditions. From the daily temperatures (Figure 6), it can be seen that there is actually no need for heating and cooling in this context. Also they exhibit the solar potential with a steady yearly radiation (Figure 5).

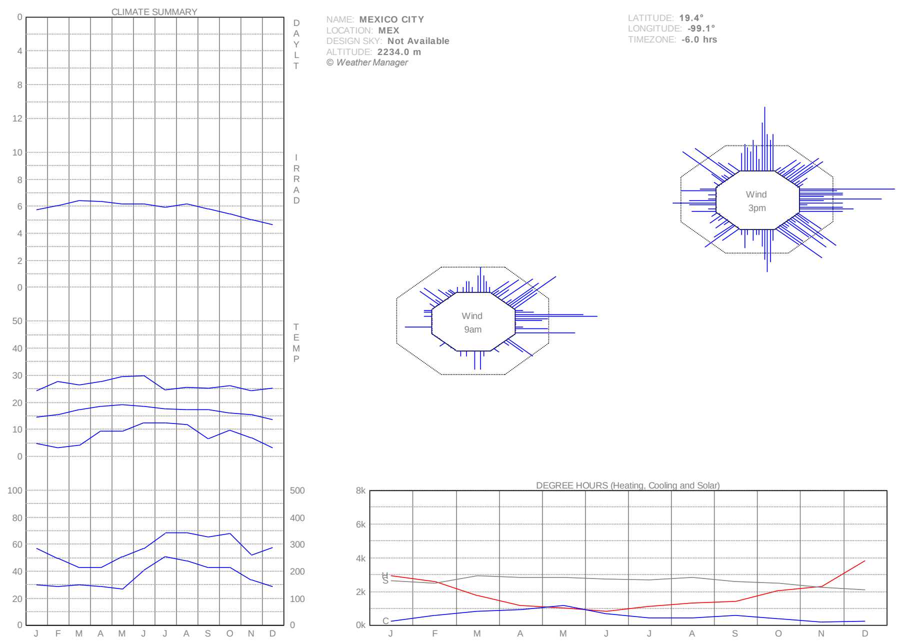


Figure 4. Mexico City climate summary (Ecotect).

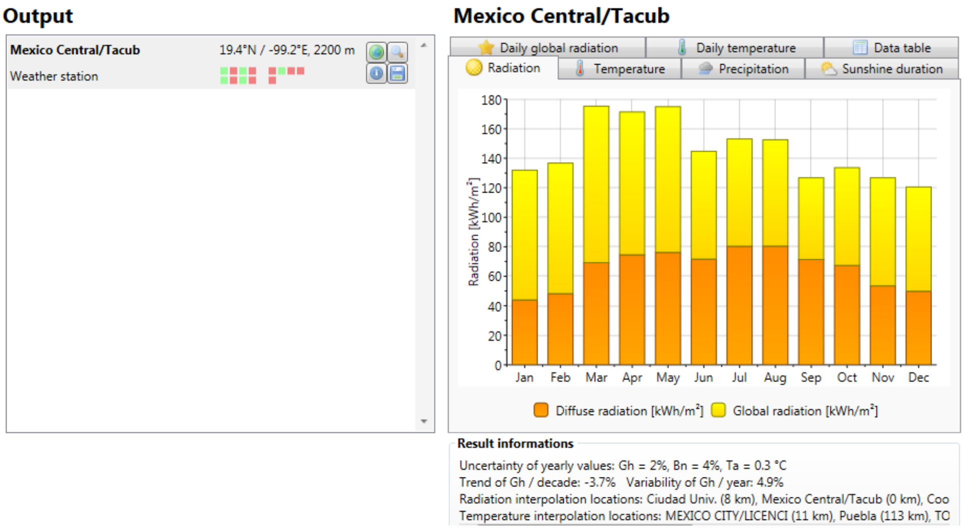


Figure 5. Mexico City yearly diffuse radiation and global radiation (Meteonorm).

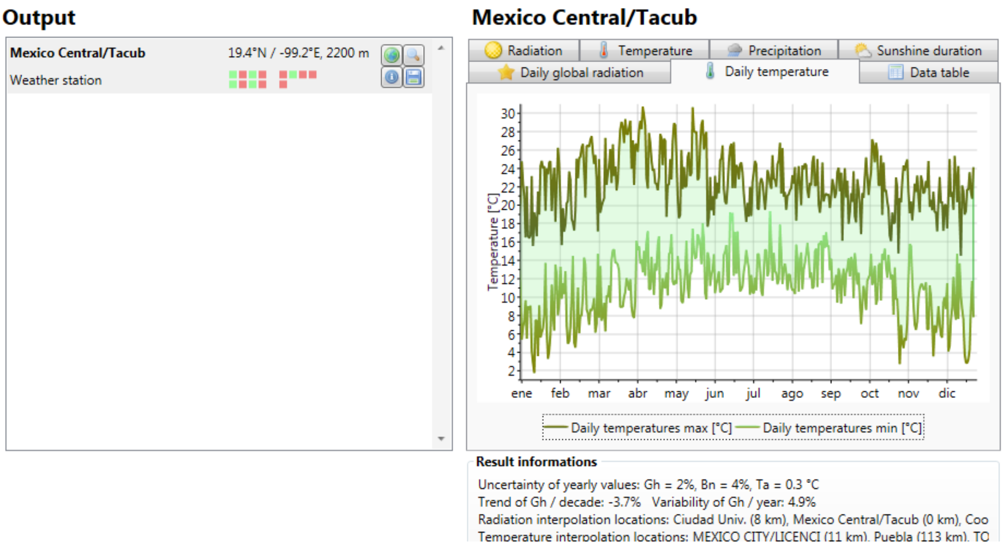


Figure 6. Mexico City yearly daily temperatures (Meteonorm).

2 METHOD

2.1 Overview

This chapter presents the approach used in the study. The intention of this procedure is to improve energy efficiency by exploring the possibility of saving electricity with energy efficient lighting, electric appliances and installing solar technology on both residences. Solar equipment for generating electricity and for heating the water.

It is important to point out that the consumption data gathered is only belonging to Herradura residence since Picacho residence is currently un-inhabited and there is no concrete lighting strategy since the construction is halted at the present moment. Therefore, the methodology implemented for Herradura will serve for estimations and suggestions for Picacho since they both have a very similar program and the same housing category.

For the energy optimization analysis the Herradura residence case served as sample with the following structure:

<u>Plans</u>

Measurements of both Herradura's and Picacho's residence were made with a digital distance measuring device to get the correct dimensions in section plans and elevations for the model. In the case of Picacho, the plans changed several times so there was a need to measure again some areas to compare with past plans.

<u>3d modelling</u>

After measuring and redrawing the plans, the next step was to model both residences in their actual condition. The dwg files were exported to Sketchup and extruded in this platform. These models served for the concluding proposals.

<u>Occupancy</u>

There was a consistent dialogue with the Matouk family to learn their typical weekly activities and schedules. The occupancy data collected from the Matouk family in Herradura was a significant base for the usage tables in the Standard case and Energy Efficient case.

Standard Case

Single family average consumption calculation for the Herradura Residence was documented. The consumption tables contain: Area, Light, Watts, Hrs per day, Hrs per month, Units, Consumption per day and consumption per month.

Market study of existing technology

A research of different elements that are integral part of the house was conducted. The study explored energy efficient alternatives in lighting, electric appliances and water pumps. A tabular format displayed concept, brand, model, specifications, and price.

Energy Efficient Case

With the analysis of lights and electric appliances available in the market, the most inefficient lights and appliances were replaced by the most efficient ones and subsequently their corresponding power was noted in the consumption tables.

Costs I Savings

Both EE case and Standard case (including their respective lights and appliances) were compared. In addition a projection study and payback time calculations were carried out. All financial data was summarized in a graphical/tabular format.

Proposal

The necessary improvements were suggested for each residence according to the market study and the calculations. As a consequence of the whole process, a retrofitting and design proposal was made. For Picacho, at the present stage, the most that can be done are estimations (taking into account the calculations and results for Herradura) since there is no data. Nevertheless, Herradura case served as a base for setting future strategies for Picacho.

2.2 Case studies

I Herradura Residence (West)

This 3-story-house was built in 1980 by military engineers. The 1985 earthquake made as a consequence this area to develop since it lies at the top of the valley on safer ground. It will be entirely renovated starting January of 2014. Table 1 displays the residence description.

Table 1. Herradura residence description.

LOT DIMENSIONS	21.90x20.10x20.37x8
LOT SURFACE	490 m^2
TOTAL BUILT	1,120 m^2
GARDEN SURFACE	122 m^2
USERS	8
OCCUPANTS PROFILE	A COUPLE WITH 3 CHILDREN, 2 MAIDS AND 1 SECURITY GUARD
ROOMS	5
BATHROOMS	5
HALF BATHS	5
LIGHTING	75 LIGHTS DOCUMENTED. REFLECTORS ARE THE MAIN KIND

Figure 7. Herradura residence.

II Picacho Residence (South)

This 2-story-house began construction in 2011 but because of recession it has stop construction in several occasions. Its foundation is entirely over volcanic rock. Pedregal neighborhood does not allow more than 2 story houses and it is only allowed to build in 30% of the lot. The residence description is displayed on Table 2.

Table 2. Picacho residence description.

LOT DIMENSIONS	19.50x60.50
LOT SURFACE	1,179 m^2
TOTAL BUILT	1,393 m^2
GARDEN SURFACE	400 m^2
USERS	7
OCCUPANTS PROFILE	A COUPLE WITH 2 CHILDREN, 3 MAIDS
ROOMS	5
BATHROOMS	7
HALF BATHS	5
LIGHTING	NOT YET DETERMINED

Figure 8. Picacho residence.

Location

Both residences are in the same geographical context, the Valley of Mexico. A valley surrounded by mountains on 3 sides, situated at about 2200 m above sea level. Both are similar in the type of housing, surface and number of users. Herradura is a residential district located in the North-West and Picacho is in the South-West.

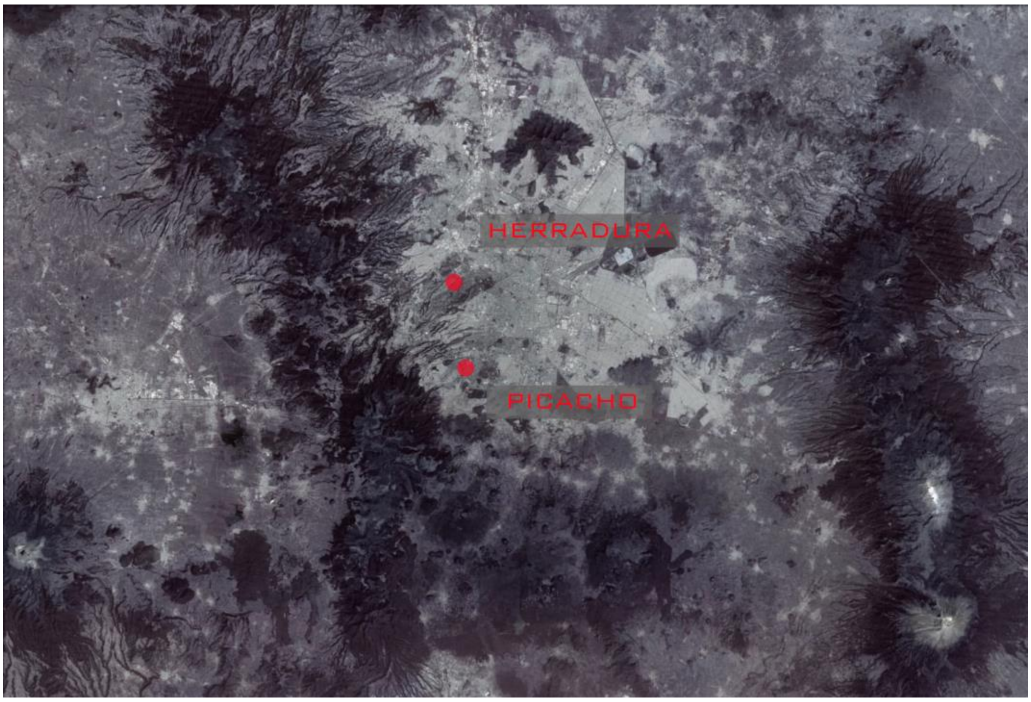


Figure 9. Herradura's and Picacho's location in the Valley of Mexico.

2.3 Occupancy

The documentation of presence in Herradura's house was done working closely with the family in order to establish an estimated number of users at certain time of the day and consumption for each day of the week. In the Valley of Mexico, Monday to Thursday are very similar in terms of schedules and activities. Friday tends to be more hectic due to heavy traffic and since is the beginning of the weekend making work and academic activities end early.

2.4 Energy consumption

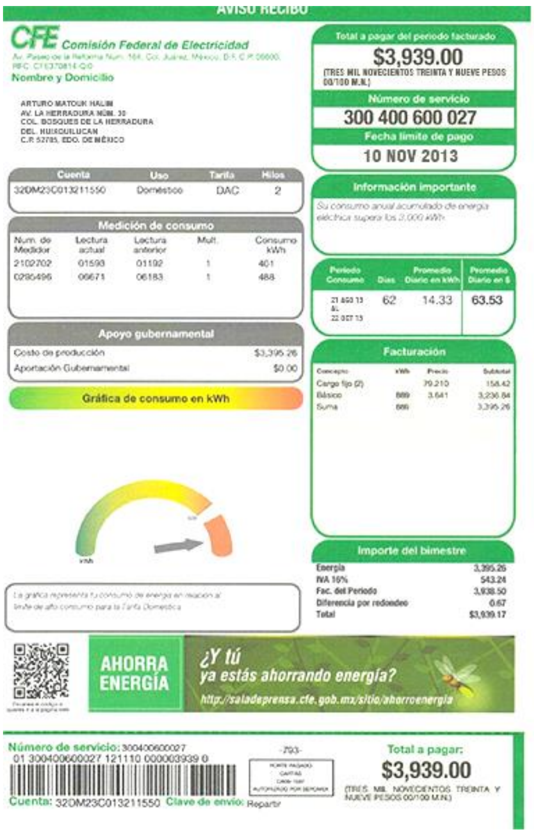
Herradura's Residence average energy consumption is above 500 kWh, therefore it falls under the High Consumption Category, the most expensive electricity tariff, which does not favor from government subsidies. The price per kWh as of 2014 is 4 MXN or 0.22 €.

Incandescent reflectors and incandescent light bulbs are the predominant lights in the house. This inefficient lights represent a significant stake of the high electricity tariffs.

With the occupancy study done there was a need to generate a very detailed declaration of the lighting and energy appliances use.

The study of Herradura's residence will dictate a series of modifications and suggestions in design, both for Herradura and Picacho residence which is currently under construction.

Figure 10 shows the last electricity bill from 2013.


AVISO RECIBO

CFE Comisión Federal de Electricidad

Nombre y Domicilio

ARTURO MATOUK HALIM
AV. LA HERRADURA NÚM. 30
COL. BOSQUES DE LA HERRADURA
DEL. HUIXQUILUCAN
C.P. 52785, EDO. DE MÉXICO

Total a pagar del periodo facturado: $3,939.00 (TRES MIL NOVECIENTOS TREINTA Y NUEVE PESOS 00/100 M.N.)

Número de servicio: 300 400 600 027

Fecha límite de pago: 10 NOV 2013

Cuenta	Uso	Tarifa	Hilos
32DM23C013211550	Doméstico	DAC	2

Medición de consumo

Num. de Medidor	Lectura actual	Lectura anterior	Mult.	Consumo kWh
2102702	01593	01192	1	401
0295496	06671	06183	1	488

Información importante

Su consumo anual acumulado de energía eléctrica supera los 3,000 kWh

Periodo Consumo	Días	Promedio Diario en kWh	Promedio Diario en $
21 AGO 13 AL 22 OCT 13	62	14.33	63.53

Apoyo gubernamental

Costo de producción	$3,395.26
Aportación Gubernamental	$0.00

Facturación

Concepto	kWh	Precio	Subtotal
Cargo fijo (2)		79.210	158.42
Básico	889	3.641	3,236.84
Suma	889		3,395.26

Gráfica de consumo en kWh

Importe del bimestre

Energía	3,395.26
IVA 16%	543.24
Fac. del Periodo	3,938.50
Diferencia por redondeo	0.67
Total	$3,939.17

AHORRA ENERGÍA

¿Y tú ya estás ahorrando energía?

http://saladeprensa.cfe.gob.mx/sitio/ahorroenergia

Número de servicio: 300400600027

01 300400600027 121110 000003939 0

Cuenta: 32DM23C013211550 Clave de envío: Repartir

Total a pagar: $3,939.00 (TRES MIL NOVECIENTOS TREINTA Y NUEVE PESOS 00/100 M.N.)

Figure 10. Herradura's electricity bill from November, 2013.

3 RESULTS

3.1 Overview

This chapter summarizes the significant results of the work. The occupancy data led to the usage hours for consumption. Four main settings are presented: Standard Case (Standard Lighting and Standard Electric Appliances), Energy Efficient Lighting and Electric Appliances, Standard case with Solar Technology and Energy Efficient Case with Solar Technology.

3.2 Occupancy

Figures 11 to 14 indicate the average presence of the 8 users. The scale from 0 to 1, where 1 represents the 100% of the users.

Figure 11 exhibits Monday to Thursday occupancy. From 6:30 hrs occupancy starts to fall 10% each hour, reaching only 33% occupancy by 9:30 hrs. Until 14:30 hrs there is a gradual rise up to 66% by 16:00 hrs. At 22:30 hrs, there is 100% occupancy.

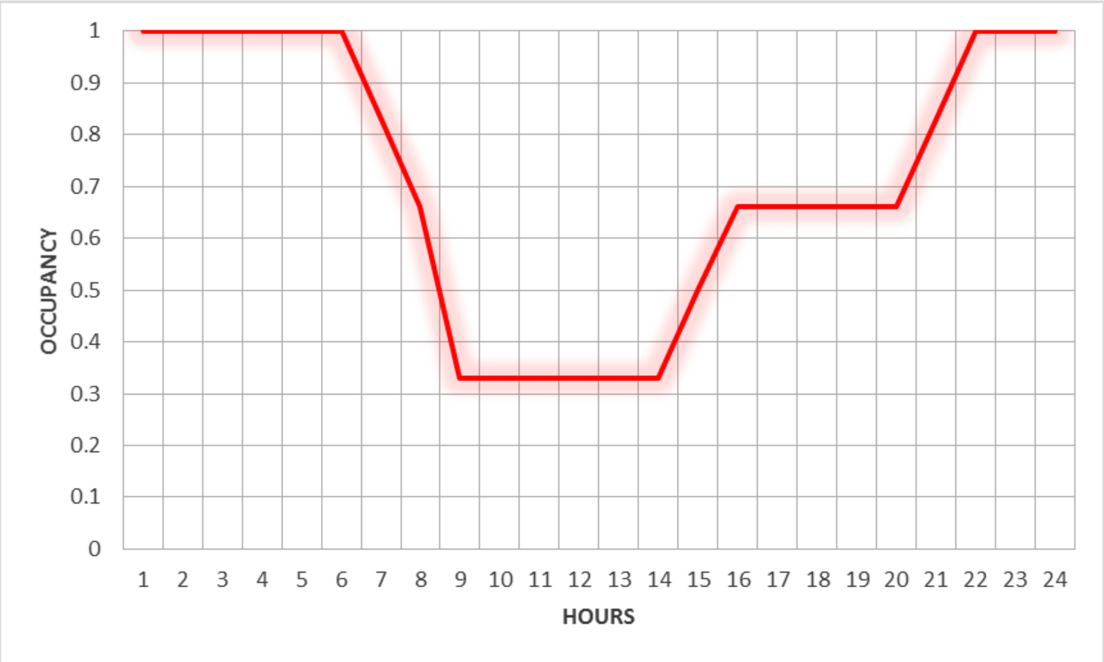


Figure 11. Herradura's residence Monday-Thursday occupancy.

As shown in Figure 12, Friday is the day of the week with most absence. Since there is more traffic this day, the users leave early and don't come back come to eat like other days. The service staff leave at 13:00 hrs for the rest of the weekend.

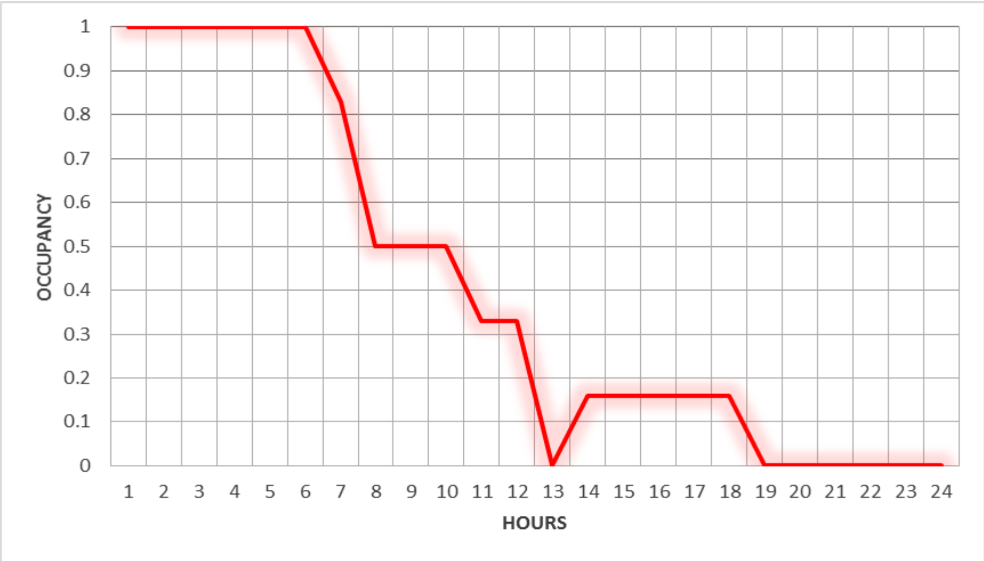


Figure 12. Herradura's residence Friday occupancy.

Since most of the family go out Friday night, Saturday's early morning has a low level of occupancy. Around 15:00 hrs the whole family go to the countryside club and come back around 21:00 hrs.

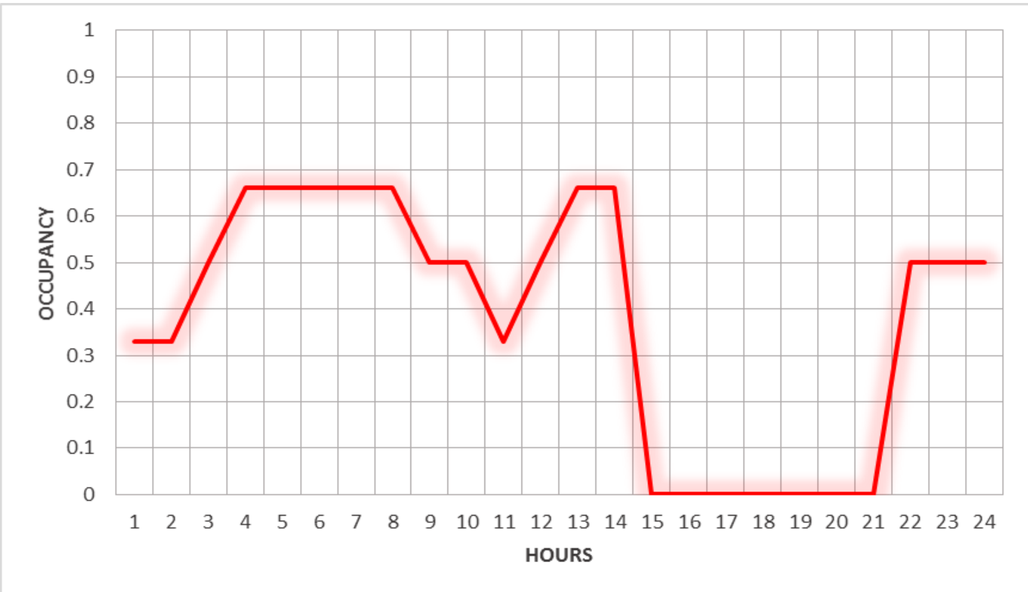


Figure13. Herradura's Residence Saturday occupancy.

Sunday is the most sedentary day of the week. It is for them an exclusive resting day. By 20:00 hrs all the users including the staff are back at home.

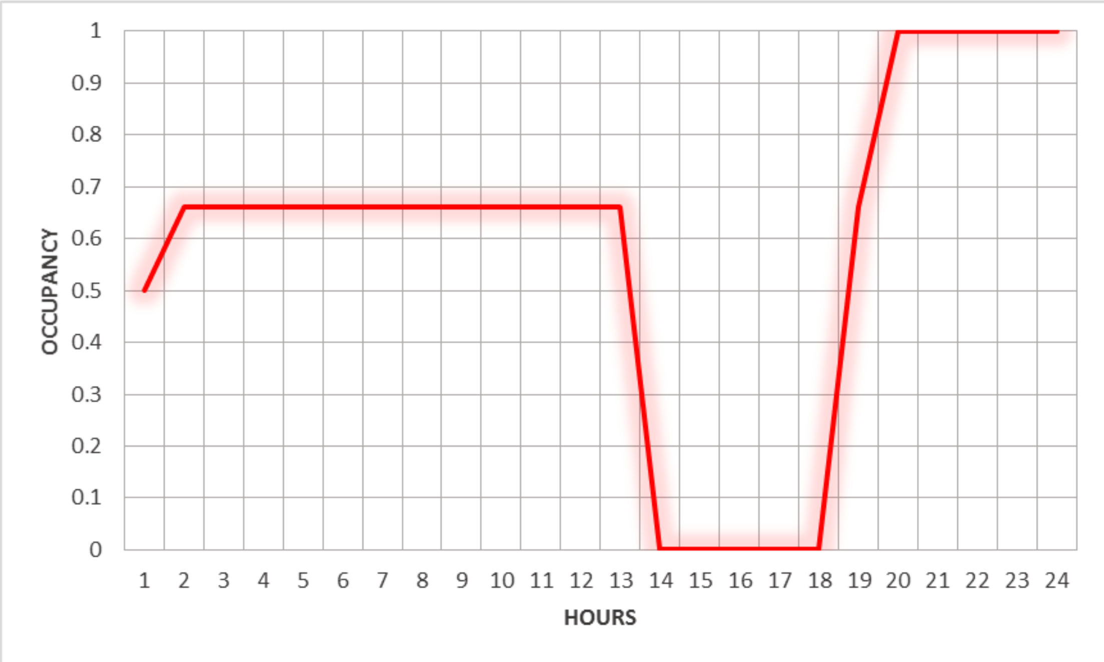


Figure 14. Herradura's residence Sunday occupancy.

3.3 Standard Lighting

On Table 3, the lighting energy consumption is displayed. The areas with the most energy consumption are the service room and the halls.

Table 3. Herradura's Basement lighting consumption.

BASEMENT:							
AREA	TR LIGHTING	POWER Watts	HRS / DAY	HRS / MONTH	UNITS	ENERGY CONS / DAY	ENERGY CONS / MONTH
LAUNDRY	INCANDESCENT BULB	50	0.67	20	2	66.67	2,000.00
SERVICE YARD	INCANDESCENT BULB	50	0.67	20	2	66.67	2,000.00
SERVICE ROOM	INCANDESCENT BULB	60	2.00	60	2	240.00	7,200.00
WC SERVICE	INCANDESCENT BULB	40	0.33	10	1	13.33	400.00
WINE CELLAR	INCANDESCENT REFLECTOR	65	0.13	4	1	8.67	260.00
STORAGE 1	INCANDESCENT BULB	50	0.13	4	2	13.33	400.00
STORAGE 2	INCANDESCENT BULB	50	0.07	2	2	6.67	200.00
MACHINE ROOM	INCANDESCENT BULB	40	0.03	1	2	2.67	80.00
WC GUESTS	INCANDESCENT BULB	75	0.50	15	1	37.50	1,125.00
STAIRCASE	INCANDESCENT BULB	40	0.50	15	1	20.00	600.00
HALLS	INCANDESCENT REFLECTOR	60	2.00	60	5	600.00	18,000.00

TOTAL	1.08	kWh DAY
	32.27	kWh MONTH
	392.56	kWh YEAR

Table 4 shows the Ground Floor lighting energy consumption. The garden has a significant consumption due to the fact that the exterior reflectors are on for several hours. The Ground Floor is the level that consumes the most energy of the whole residence.

Table 4. Herradura's Ground Level lighting consumption.

GROUND LEVEL:							
AREA	TR LIGHTING	POWER Watts	HRS / DAY	HRS / MONTH	UNITS	ENERGY CONS / DAY	ENERGY CONS / MONTH
GARAGE	FLUORESCENT LAMP	32	1.00	30.00	12	384.00	11,520.00
GARDEN	INCANDESCENT REFLECTOR	150	3.00	72.00	4	1,800.00	43,200.00
GARDEN STORAGE	CFL	28	0.03	2.00	1	0.93	56.00
GARDEN WC	INCANDESCENT BULB	50	0.02	0.66	1	1.10	33.00
VESTIBULE	INCANDESCENT REFLECTOR	100	3.00	66.00	2	600.00	13,200.00
MAIN LOBBY	INCANDESCENT REFLECTOR	100	4.00	88.00	2	800.00	17,600.00
LIVING ROOM	INCANDESCENT REFLECTOR	100	4.00	92.00	4	1,600.00	36,800.00
DINING ROOM	INCANDESCENT REFLECTOR	100	2.50	56.00	4	1,000.00	22,400.00
KITCHEN	INCANDESCENT REFLECTOR	65	5.00	100.00	4	1,300.00	26,000.00
WC GUESTS	CFL	42	0.07	2.00	1	2.80	83.92
GUEST ROOM	INCANDESCENT REFLECTOR	100	3.00	20.00	2	600.00	4,000.00
WC GUEST ROOM	CFL	28	0.50	15.00	1	14.00	420.00
TERRACE	INCANDESCENT REFLECTOR	100	3.00	72.00	3	900.00	21,600.00

TOTAL	6.56	kWh DAY
	196.91	kWh MONTH
	71,873.21	kWh YEAR

For the First Level, the terrace is the area with the most energy waste due to the incandescent exterior reflectors and the hours on operation (Table 5).

Table 5. Herradura's First Level lighting consumption.

1 LEVEL:							
AREA	TR LIGHTING	POWER Watts	HRS / DAY	HRS / MONTH	UNITS	ENERGY CONS / DAY	ENERGY CONS / MONTH
TV ROOM	INCANDESCENT REFLECTOR	100	1.00	30.00	4	400.00	12,000.00
MAIN ROOM	INCANDESCENT REFLECTOR	150	2.00	36.00	2	600.00	10,800.00
CHANGING ROOM	INCANDESCENT REFLECTOR	75	0.50	15.00	2	75.00	2,250.00
WC MAIN ROOM	CFL	42	1.25	32.00	1	52.50	1,344.00
ROOM 1	INCANDESCENT REFLECTOR	100	3.00	66.00	2	600.00	13,200.00
WC R1	CFL	28	0.50	15.00	1	14.00	420.00
ROOM 2	INCANDESCENT REFLECTOR	100	4.00	96.00	2	800.00	19,200.00
WC R2	CFL	42	0.50	15.00	1	21.00	630.00
ROOM 3	INCANDESCENT REFLECTOR	150	2.00	60.00	2	600.00	18,000.00
WC R3	INCANDESCENT BULB	50	0.50	15.00	1	25.00	750.00
TERRACE	INCANDESCENT REFLECTOR	100	3.00	90.00	3	900.00	27,000.00
STAIRCASE	INCANDESCENT BULB	60	0.50	15.00	1	30.00	900.00

TOTAL	3.55	kWh DAY
	106.49	kWh MONTH
	1,295.68	kWh YEAR

The annex (Table 6) represents the smallest part in energy consumption terms. This is mainly on the grounds that is the least occupied area in the residence, it is only used in social events.

Table 6. Herradura's Annex lighting consumption.

ANNEX:							
AREA	TR LIGHTING	POWER Watts	HRS / DAY	HRS / MONTH	UNITS	ENERGY CONS / DAY	ENERGY CONS / MONTH
1 LEVEL:							
LOUNGE	FLUORESCENT LAMP	32	0.50	15.00	6	96.00	2,880.00
KITCHEN	INCANDESCENT REFLECTOR	75	0.17	5.00	2	24.99	749.70
WC GUESTS WOMEN	CFL	23	0.08	2.50	1	1.92	57.48
WC GUESTS MEN	CFL	23	0.08	2.50	1	1.92	57.48
STAIRCASE	LED	4	0.50	12.00	8	16.00	384.00
2 LEVEL:							
WC	CFL	23	0.17	5.00	1	3.83	114.95
BAR	INCANDESCENT REFLECTOR	60	0.25	7.50	2	30.00	900.00
BILLIARD	INCANDESCENT REFLECTOR	60	0.25	7.50	2	30.00	900.00

TOTAL	0.20	kWh DAY
	6.04	kWh MONTH
	73.53	kWh YEAR

3.4 Standard Electric Appliances

When it comes to electric appliances, the Basement is the level with the most energy consumption. The water pump is the most energy consuming equipment, followed by the drying machine and washing machine (Table 7).

Table 7. Herradura's Basement electric appliances consumption.

BASEMENT:							
AREA	ELECTRIC APPLIANCES	POWER Watts	HRS / DAY	HRS / MONTH	UNITS	ENERGY CONS / DAY	ENERGY CONS / MONTH
LAUNDRY	CLOTHES WASHING	700	0.44	13.33	1	311.03	9,331.00
	CLOTHES DRYER	4400	0.44	13.33	1	1,955.07	58,652.00
SERVICE YARD	CLOTHES IRON	1100	0.17	5.00	1	183.33	5,500.00
SERVICE ROOM	RADIO	50	1.07	32.00	1	53.33	1,600.00
	ALARM CLOCK	5	24.00	720.00	1	120.00	3,600.00
	TV	110	1.60	48.00	1	176.00	5,280.00
WC SERVICE							
WINE CELLAR							
STORAGE 1	VACUUM CLEANER	740	0.13	4.00	1	98.67	2,960.00
STORAGE 2							
MACHINE ROOM	WATER PUMP (1HP)	1500	2.80	84.00	1	4,200.00	126,000.00
WC GUESTS							
HALLS							

TOTAL		
	7.10	kWh DAY
	212.92	kWh MONTH
	2,590.56	kWh YEAR

The only relevant energy consumption in the Ground Level (Table 8) is from the refrigerator. Nevertheless, it was bought 4 years ago and is not considered for replacement.

Table 8. Herradura's Ground Level electric appliances consumption.

GROUND LEVEL:							
AREA	TR LIGHTING	POWER Watts	HRS / DAY	HRS / MONTH	UNITS	ENERGY CONS / DAY	ENERGY CONS / MONTH
GARAGE	GARAGE ELECTRIC DOOR	350	0.08	2.33	1	27.18	815.50
GARDEN	LAWN MOWER	0	0.00	0.00	1	0.00	0.00
GARDEN STORAGE							
GARDEN WC							
VESTIBULE							
MAIN LOBBY							
LIVING ROOM	CORDLESS PHONE	2	24.00	720.00	1	48.00	1,440.00
DINING ROOM							
KITCHEN	COFFE MAKER	1000	0.22	6.60	1	220.00	6,600.00
	COFFE GRINDER	100	0.00	0.00	1	0.00	0.00
	BLENDER	300	0.00	0.12	1	1.20	36.00
	OVEN	0	0.67	20.00	1	0.00	0.00
	TOASTER	1400	0.13	4.00	1	186.67	5,600.00
	REFRIGERATOR/FREEZER	150	24.00	720.00	1	3,600.00	108,000.00
	WATER PURIFIER	800	0.00		1	0.00	0.00
	RADIO	15	1.07	32.00	1	16.00	480.00
	MICROWAVE	1100	0.40	12.00	1	440.00	13,200.00
WC GUESTS							
WC GR							
TERRACE							

TOTAL		
	4.54	kWh DAY
	136.17	kWh MONTH
	1,656.75	kWh YEAR

The first level (Table 9) shows a moderate consumption although this is due to the fact that the users do not spend that much time in their bedrooms. The desktop computer is the electric appliance that consumes the most energy. In the TV Room, it is reported that some appliances are on standby mode.

Table 9. Herradura's First Level electric appliances consumption.

1 LEVEL:							
AREA	TR LIGHTING	POWER Watts	HRS / DAY	HRS / MONTH	UNITS	ENERGY CONS / DAY	ENERGY CONS / MONTH
TV ROOM	TV	150	2.33	70.00	1	350.00	10,500.00
	TV (STAND BY)	6	20.50	615.00	1	123.00	3,690.00
	SATELLITE SKY	30	2.33	70.00	1	70.00	2,100.00
	SKY (STAND BY)	12	20.50	615.00	1	246.00	7,380.00
	DVD	40	0.40	12.00	1	16.00	480.00
	DVD (STAND BY)	3.5	20.50	615.00	1	71.75	2,152.50
	WI-FI ROUTER	6	24.00	720.00	1	144.00	4,320.00
	CORDLESS PHONE	2	24.00	720.00	1	48.00	1,440.00
MAIN ROOM	CLOCK RADIO	5	24.00	720.00	1	120.00	3,600.00
	LAPTOP	89	0.67	20.00	1	59.33	1,780.00
	CELL PHONE CHARGER	11.78	2.80	84.00	1	32.98	989.52
	FLAT-SCREEN	230	1.00	30.00	1	230.00	6,900.00
	FLAT-SCREEN STANDBY	6	22.50	675.00	1	135.00	4,050.00
	SATELLITE SKY	30	1.00	30.00	1	30.00	900.00
	SKY STANDBY	12	22.50	675.00	1	270.00	8,100.00
CHANGING ROOM							
WC MAIN ROOM	HAIR DRYER	1200	0.16	4.66	1	186.40	5,592.00
	SHAVER	15	0.16	4.66	1	2.33	69.90
ROOM 1	DESKTOP COMPUTER	300	3.33	100.00	1	1,000.00	30,000.00
	PRINTER	100	0.07	2.00	1	6.67	200.00
	CELL PHONE CHARGER	9.25	3.00	90.00	1	27.75	832.50
	IPAD CHARGER	10	2.00	60.00	1	20.00	600.00
WC R1/R2	HAIR DRYER	1200	0.16	4.66	1	186.40	5,592.00
ROOM 2	TV	150	1.07	32.00	1	160.00	4,800.00
	TV (STAND BY)	6	22.00	660.00	1	132.00	3,960.00
	SATELLITE SKY	30	1.07	32.00	1	32.00	960.00
	SKY (STAND BY)	12	22.00	660.00	1	264.00	7,920.00
	CELL PHONE CHARGER	5	2.80	84.00	1	14.00	420.00
	ALARM CLOCK	10	24.00	720.00	1	240.00	7,200.00
	IPOD CHARGER	5	1.60	48.00	1	8.00	240.00
ROOM 3	RADIO CLOCK	5	24.00	720.00	1	120.00	3,600.00
WC R3							
TERRACE							
STAIRCASE							

TOTAL	4.35	**kWh DAY**
	130.37	**kWh MONTH**
	1,586.15	**kWh YEAR**

Table 10 shows the Annex which is the area with the least electric appliances. The mini fridge is the electric appliance that consumes the most energy.

Table 10. Herradura's Annex electric appliances consumption.

ANNEX:							
AREA	TR LIGHTING	POWER Watts	HRS / DAY	HRS / MONTH	UNITS	ENERGY CONS / DAY	ENERGY CONS / MONTH
1 LEVEL:							
LOUNGE	IPOD DVD MUSIC SYSTEM	50	0.53	16	1	26.67	800
	CORDLESS PHONE	2	24.00	720	1	48.00	1440
KITCHEN	MINI FRIDGE	120	0.53	16	1	64.00	1920
	MICROWAVE	800	0.01	0.2	1	5.33	160
WC GUESTS WOMEN							
WC GUESTS MEN							
STAIRCASE							
2 LEVEL:							
WC							
BAR							
BILLIARD							

TOTAL	0.14	**kWh DAY**
	4.32	**kWh MONTH**
	52.56	**kWh YEAR**

3.5 Market study

The market study explored energy efficient alternatives in lighting, electric appliances and solar technology. As a consequence of the NAFTA agreement the Mexican market is much more open. This is reflected in the variety of products available to the customers. The market study summarizes the best alternatives of each field.

For the Herradura residence the clients agreed to change all the incandescent lights and replace them with energy efficient ones.

The LEDs stand out among other lights due to their low wattage, light intensity and long duration. They are part of a new generation of lights but its use have not been extensive nationwide due to its cost. It is important to note that all the lights displayed on Table 11 are chosen to replace the old lighting.

Table 11. Energy efficient lights (PHILLIPS MEXICO).

LIGHTING										
										
NAME	LED PAR38	LED PAR20	LED R20	T5	REFLECTOR 117 LED	TWISTER SENSOR	LED MR16	MINI TWISTER	RAIL HALVA	HALOGEN DI MR
WATTS	17	7	6	13	8.7	15	7	9,18	3x35W	20
LIFE	45,000	45,000	45,000	25,000	35,000	8,000	40,000	12,000	40,000	5,000
PRICE	555 MXN	429 MXN	429 MXN	125 MXN	499 MXN	129 MXN	479 MXN	107 (x3) MXN	1099 MXN	131.27 MXN

There are many models of energy efficient washing machines (Table 12) available. Samsung is recognized for a very elegant line in washing machines and but also for their high prices. Whirpool offers very low prices but their models are somewhat austere. The Matouk family selected the model WM2650HWA from LG (139.7 watts).

Table 12. Energy efficient washing machines (PROFECO).

WASHING MACHINE					
BRAND	SAMSUNG	LG	WHIRPOOL	FRIGIDAIRE	MAYTAG
MODEL	WF431ABP/XAX	WM2650HWA	7MWFW95HEY	FAFS4073NW	7MMHW7000Y
WATTS	1454.8	139.7	140	186.4	142.4
LOAD	17	17	17	17	17
WATER CONS (LTS)	61.6	51.6	78.2	46	73.4
PRICE	36,075.52 MXN	13,065.62 MXN	22,990.00 MXN	14,499.00 MXN	21,539.00 MXN

For the drying machines (Table 13) several models from loads of 15 to 24 kg were analyzed. The residents preferred the TD-V122466/12 (229.4 watts) from LG. Apart from the energy efficiency, performance and design, a strong reason for them was the fact that they will deal with the same company (LG) for maintenance and service of their laundry appliances.

Table 13. Energy efficient drying machines (PROFECO).

DRYING MACHINE					
BRAND	WHIRPOOL	LG	SAMSUNG	EASY	FRIGIDAIRE
MODEL	7MWGD8300AW	TD-V122466/12	DV337AGG	SF4 1124PFWW/11	A6060000ES/114
WATTS	152.7	229.4	414.9	316.4	260.5
LOAD	24	17	17	17	17
PRICE	14,499.00 MXN	13,065.62 MXN	22,990.00 MXN	14,499.00 MXN	21,539.00 MXN

The following energy efficient water pumps (Table 14) are good choices to substitute the actual water pump. Both with 1hp and similar prices. The Pedrollo model was chosen for replacement.

Table 14. Energy efficient water pumps (PEDROLLO MEXICO, TRUPER).

WATER PUMP		
BRAND	PEDROLLO	TRUPER
WATER FLOW	90 LPM	50 LPM
MODEL	CPM620	HIDR-1
WATTS	750	746
POWER	1 HP	1 HP
PRICE	2,425.00 MXN	2,405 MXN

Solartec offers a wide range of solar panels (monocrystalline, polycrystalline and thin film) from 245 to 290 watts. This company has a good reputation in North America and it also reaches Europe and Latin America. The solar panels exhibited on Table 15 have and average lifespan of 25 years.

Table 15. Solar panels.

SOLAR PANELS						
BRAND	TYPE	MODEL	QTY	SPECIFICATIONS	PRICE	OBSERVATIONS
SOLARTEC	MONOCRYSTALLINE	S60MC	1	1640mm x 992mm	4,724.00 MXN	245 W
SOLARTEC	MONOCRYSTALLINE	S60MC	1	1640mm x 992mm	4,820.00 MXN	250 W
SOLARTEC	MONOCRYSTALLINE	S60MC	1	1640mm x 992mm	4,917.00 MXN	255 W
SOLARTEC	MONOCRYSTALLINE	S60MC	1	1640mm x 992mm	5,013.00 MXN	260 W
SOLARTEC	MONOCRYSTALLINE	S60MC	1	1640mm x 992mm	5,110.00 MXN	265 W
SOLARTEC	MONOCRYSTALLINE	S72MC6	1	1955mm x 992mm	5,206.00 MXN	270 W
SOLARTEC	MONOCRYSTALLINE	S72MC6	1	1955mm x 992mm	5,400.00 MXN	280 W
SOLARTEC	MONOCRYSTALLINE	S72MC6	1	1955mm x 992mm	5,600.00 MXN	290 W
ECOTECNIA	POLYCRYSTALINE	KIT 6	6	NA	2,962.47 USD	230 W
SINERPOL	POLYCRYSTALINE	KIT 4	4	1500mm x 668 mm x 46 mm	50,460.00 MXN	4 kWh/DAY
CASOLAR	POLYCRYSTALINE	SERIES ABSOL MFV-140-C	24	1.95 X 90 X .07	9,770.00 USD	140 W

The solar heaters from Ecovita offer a good performance due its 3-layered-tubes. On Table 16, 2 systems are shown: gravity and pressurized. The other main company (Generación Solar) counts with a low, medium and high pressure systems. Generación Solar have more variety than Ecovita but also higher prices.

Table 16. Solar heaters.

SOLAR HEATERS						
BRAND	MODEL	CAPACITY	TUBES	USERS	PRICE	OBSERVATIONS
ECOVITA	EV-10	130 LTS	10	3	4,400 MXN	GRAVITY SYSTEM
ECOVITA	EV-16	186 LTS	16	5	6,100 MXN	GRAVITY SYSTEM
ECOVITA	EV-20	239 LTS	20	6	7,300 MXN	GRAVITY SYSTEM
ECOVITA	EV-24	283 LTS	24	8	8,900 MXN	GRAVITY SYSTEM
ECOVITA	HP-16	150 LTS	16	5	12,200 MXN	HIDROPNEUMATIC USE
ECOVITA	HP-24	215 LTS	24	7	15,800 MXN	HIDROPNEUMATIC USE
ECOVITA	HP-30	280 LTS	30	10	18,600 MXN	HIDROPNEUMATIC USE
ECOVITA	HP-31	150 LTS	(CRYSTAL)	5	7,300 MXN	GRAVITY OR PRESSURIZED SYSTEM
GENERACION SOLAR	NA	120 LTS	10	3	6,500 MXN	LOW PRESSURE SYSTEM
GENERACION SOLAR	NA	150 LTS	12	4	7,600 MXN	LOW PRESSURE SYSTEM
GENERACION SOLAR	NA	175 LTS	15	5	8,700 MXN	LOW PRESSURE SYSTEM
GENERACION SOLAR	NA	206 LTS	18	6	9,800 MXN	LOW PRESSURE SYSTEM
GENERACION SOLAR	NA	228 LTS	20	7	10,900 MXN	LOW PRESSURE SYSTEM
GENERACION SOLAR	NA	273 LTS	24	8	11,990 MXN	LOW PRESSURE SYSTEM
GENERACION SOLAR	NA	175 LTS	15	5	13,000 MXN	MEDIUM PRESSURE SYSTEM
GENERACION SOLAR	NA	157 LTS	12	4	14,800 MXN	HIGH PRESSURE SYSTEM
GENERACION SOLAR	NA	184 LTS	14	5	15,500 MXN	HIGH PRESSURE SYSTEM
GENERACION SOLAR	NA	202 LTS	16	6	16,900 MXN	HIGH PRESSURE SYSTEM
GENERACION SOLAR	NA	290 LTS	25	8	21,800 MXN	HIGH PRESSURE SYSTEM

3.6 Energy Efficient Lighting

Based on the market study, the following implementations are suggested from Table 17 to 21. The residents in Herradura already approved the complete replacement of incandescent lighting for energy efficient one. Conserving the same usage, the following tables shows the modifications of their corresponding wattages.

Table 17. Herradura's Basement energy efficient lighting consumption.

BASEMENT:							
AREA	TR LIGHTING	POWER Watts	HRS / DAY	HRS / MONTH	UNITS	ENERGY CONS / DAY	ENERGY CONS / MONTH
LAUNDRY	CFL TWISTER SENS	15	0.67	20	2	20.00	600.00
SERVICE YARD	CFL TWISTER2	9	0.67	20	2	12.00	360.00
SERVICE ROOM	CFL MINI TWISTER	18	2.00	60	2	72.00	2,160.00
WC SERVICE	CFL MINI TWISTER	9	0.33	10	1	3.00	90.00
WINE CELLAR	HALOGEN DI MR	20	0.13	4	1	2.67	80.00
STORAGE 1	HALOGEN DI MR	20	0.13	4	2	5.33	160.00
STORAGE 2	HALOGEN DI MR	20	0.07	2	2	2.67	80.00
MACHINE ROOM	CFL TWISTER 2	9	0.03	1	2	0.60	18.00
WC GUESTS	CFL MINI TWISTER	13	0.50	15	1	6.50	195.00
STAIRCASE	LED R20	6	0.50	15	17	51.00	1,530.00
HALLS	CFL TWISTER SENS	15	2.00	60	5	150.00	4,500.00

TOTAL	0.33	kWh DAY
	9.77	kWh MONTH
	118.90	kWh YEAR

The Ground Level would have an energy consumption of less than 30 kWh per month as seen on Table 18. Above the terrace, fluorescent t5 will be installed next to the steel beams.

Table 18. Herradura's Ground Level energy efficient lighting consumption.

GROUND LEVEL:							
AREA	TR LIGHTING	POWER Watts	HRS / DAY	HRS / MONTH	UNITS	ENERGY CONS / DAY	ENERGY CONS / MONTH
GARAGE	FLUORESCENT LAMP T5 ECO	13	1.00	30.00	12	156.00	4,680.00
GARDEN	LED 117 REFLECTOR	9	3.00	72.00	4	108.00	2,592.00
GARDEN STORAGE	CFL MINI TWISTER	9	0.03	2.00	1	0.30	18.00
GARDEN WC	INCANDESCENT BULB	50	0.02	0.66	1	1.10	33.00
VESTIBULE	LED MR16	7	3.00	66.00	2	42.00	924.00
MAIN LOBBY	LED PAR38	17	4.00	88.00	2	136.00	2,992.00
LIVING ROOM	FLUORESCENT LAMP T5 ECO	13	4.00	92.00	4	208.00	4,784.00
DINING ROOM	FLUORESCENT LAMP T5 ECO	13	2.50	56.00	4	130.00	2,912.00
KITCHEN	LED PAR38	17	5.00	100.00	4	340.00	6,800.00
WC GUESTS	CFL TWISTER SENS	15	0.07	2.00	1	1.00	29.97
GUEST ROOM	LED PAR38	17	3.00	20.00	2	102.00	680.00
WC GUEST ROOM	LED PAR20	7	0.50	15.00	1	3.50	105.00
TERRACE	FLUORESCENT LAMP T5 ECO	13	3.00	72.00	3	117.00	2,808.00

TOTAL	0.98	kWh DAY
	29.36	kWh MONTH
	10,715.66	kWh YEAR

The First Level (Table 19) employs mostly LEDs for bedrooms and bathrooms, the terrace like the level below, will have warm intensity t5 tubes along the beams of the new structure.

Table 19. Herradura's First Level energy efficient lighting consumption.

1 LEVEL:							
AREA	TR LIGHTING	POWER Watts	HRS / DAY	HRS / MONTH	UNITS	ENERGY CONS / DAY	ENERGY CONS / MONTH
TV ROOM	FLUORESCENT LAMP T5 ECO	13	1.00	30.00	4	52.00	1,560.00
MAIN ROOM	LED PAR38	17	2.00	36.00	2	68.00	1,224.00
CHANGING ROOM	LED PAR20	7	0.50	15.00	2	7.00	210.00
WC MAIN ROOM	LED PAR38	17	1.25	32.00	1	21.25	544.00
ROOM 1	LED PAR38	17	3.00	66.00	2	102.00	2,244.00
WC R1	LED PAR20	7	0.50	15.00	1	3.50	105.00
ROOM 2	LED PAR38	17	4.00	96.00	2	136.00	3,264.00
WC R2	LED PAR20	7	0.50	15.00	1	3.50	105.00
ROOM 3	LED PAR38	17	2.00	60.00	2	68.00	2,040.00
WC R3	LED PAR20	7	0.50	15.00	1	3.50	105.00
TERRACE	FLUORESCENT LAMP T5 ECO	13	3.00	90.00	3	117.00	3,510.00
STAIRCASE	LED R20	6	0.50	15.00	17	51.00	1,530.00

TOTAL	0.55	kWh DAY
	16.44	kWh MONTH
	200.03	kWh YEAR

The annex used to be a squash court. After the renovation it will have a lounge appearance and a second level for billiard and entertainment. Table 20 shows the lights selected for the annex section.

Table 20. Herradura's Annex energy efficient lighting consumption.

ANNEX:							
AREA	TR LIGHTING	POWER Watts	HRS / DAY	HRS / MONTH	UNITS	ENERGY CONS / DAY	ENERGY CONS / MONTH
1 LEVEL:							
LOUNGE	RAIL HALVA	35	0.50	15.00	12	210.00	6,300.00
KITCHEN	LED PAR38	17	0.17	5.00	2	5.66	169.93
WC GUESTS WOMEN	LED MR16	7	0.08	2.50	2	1.17	34.99
WC GUESTS MEN	LED MR16	7	0.08	2.50	2	1.17	34.99
STAIRCASE	LED R20	6	0.50	12.00	17	51.00	1,224.00
2 LEVEL:							
WC	LED MR16	7	0.1666	4.998	2	2.3324	69.972
BAR	LED PAR38	17	0.25	7.50	2	8.50	255.00
BILLIARD	LED PAR38	17	0.25	7.50	2	8.50	255.00

TOTAL	0.28	kWh DAY
	8.34	kWh MONTH
	101.52	kWh YEAR

3.7 Energy Efficient Electric Appliances

The electric appliances that the Matouk family agreed to replace are: washing machine, drying machine and water pump. These are exactly the ones that consume the most electricity. Table 21 highlights the energy efficient electric appliances. The replacement will reduce by 26% the energy consumption for appliances and equipment.

Table 21. Herradura's Basement energy efficient electric appliances consumption.

BASEMENT:							
AREA	ELECTRIC APPLIANCES	POWER Watts	HRS / DAY	HRS / MONTH	UNITS	ENERGY CONS / DAY	ENERGY CONS / MONTH
LAUNDRY	CLOTHES WASHING	139.7	0.44	13.33	1	62.07	1,862.20
	CLOTHES DRYING MACHINE	229.4	0.44	13.33	1	101.93	3,057.90
SERVICE YARD	CLOTHES IRON	1100	0.17	5.00	1	183.33	5,500.00
SERVICE ROOM	RADIO	50	1.07	32.00	1	53.33	1,600.00
	ALARM CLOCK	5	24.00	720.00	1	120.00	3,600.00
	TV	110	1.60	48.00	1	176.00	5,280.00
WC SERVICE							
WINE CELLAR							
STORAGE 1	VACUUM CLEANER	740	0.13	4.00	1	98.67	2,960.00
STORAGE 2							
MACHINE ROOM	WATER PUMP (1HP)	750	2.80	84.00	1	2,100.00	63,000.00
WC GUESTS							
HALLS							

TOTAL	2.90	kWh DAY
	86.86	kWhMONTH
	1,056.80	kWh YEAR

The electric appliance that consumes the most energy is the water pump. It will be replaced for the Petrollo water pump this year. Next, a comparison of electric appliances monthly average energy use (Figure 15).

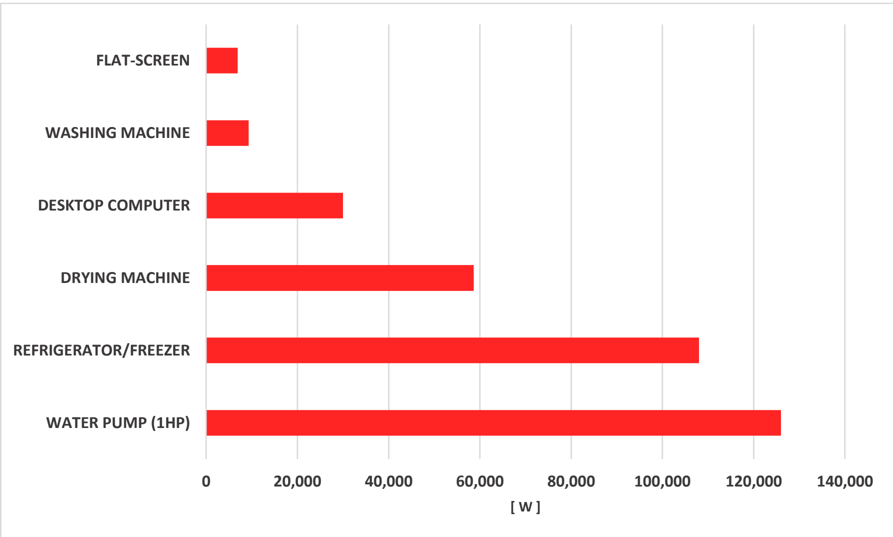


Figure 15. Comparison of electric appliances use.

3.8 Comparison

On Figure 16, it is shown the average monthly energy usage per areas of the Herradura residence in both standard and energy efficient case. The monthly values in the following tables are calculated by dividing the annual value by 12.

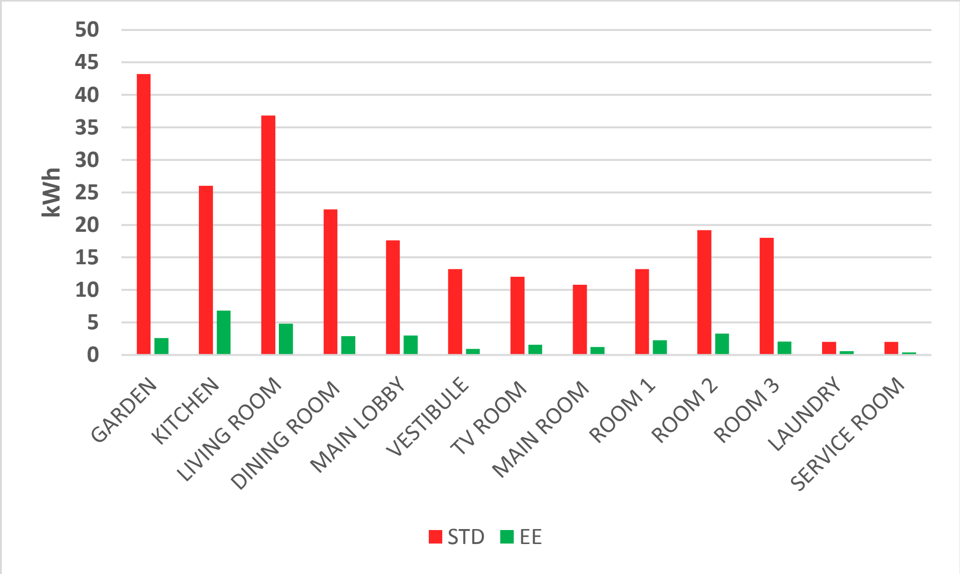


Figure 16. Lighting energy use per space.

Figure 17 shows the costs of both standard and energy efficient case, in monthly and yearly periods.

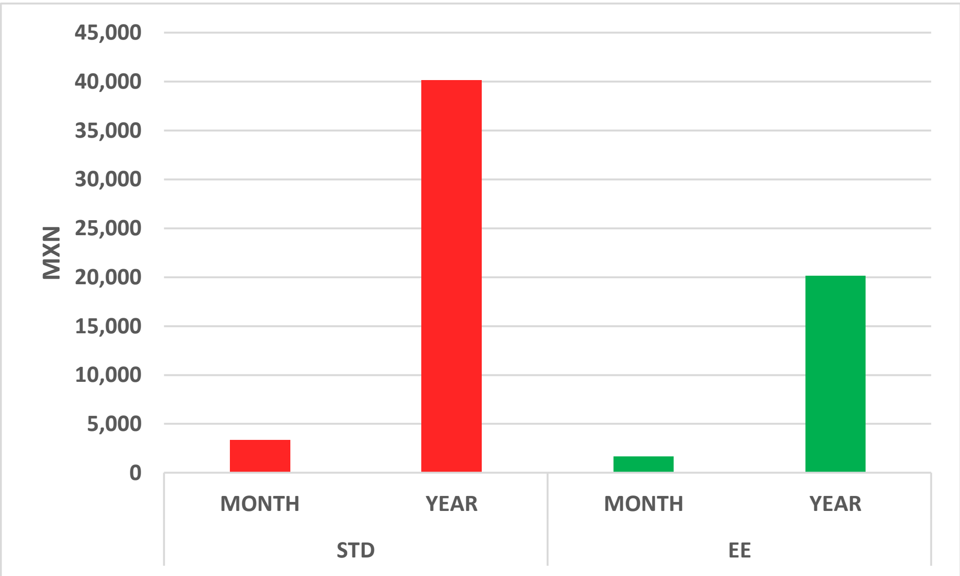


Figure 17. Lighting total energy costs.

Figure 18 shows the monthly and yearly energy consumption of both cases (standard and energy efficient).

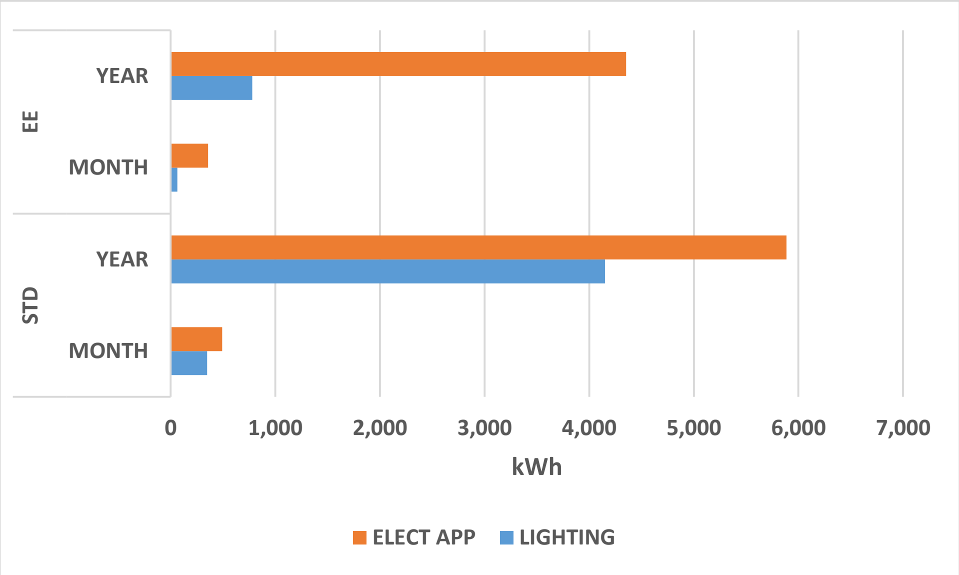


Figure 18. Lighting and electric appliances consumption.

The corresponding (monthly and yearly) costs of the standard and energy efficient case are displayed on Figure 19.

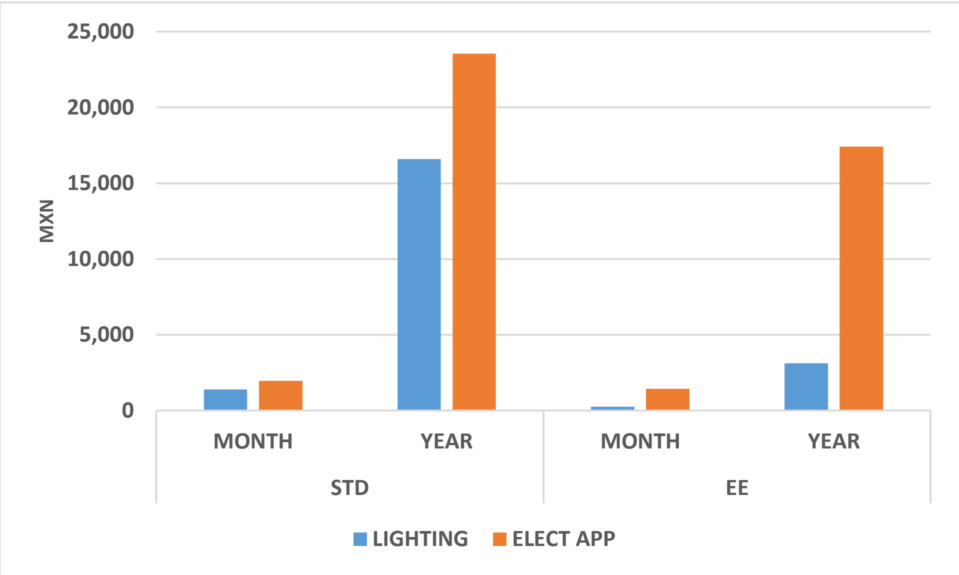


Figure 19. Lighting and electric appliances costs.

Following, a comparison of the total (average monthly and yearly) energy consumption is summarized in Figure 20.

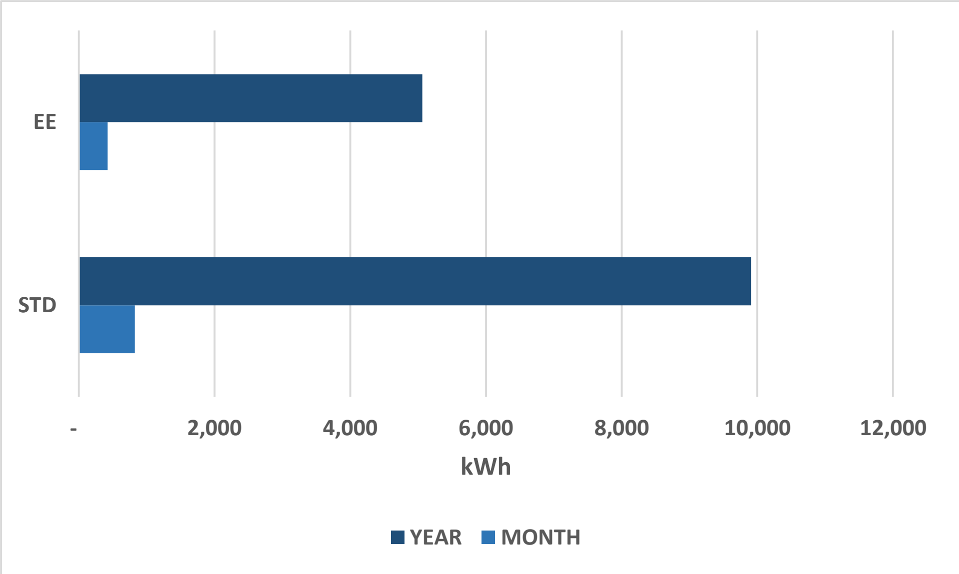


Figure 20. Total energy consumption.

3.9 Financial Analysis

Table 22 compares the Total electricity consumption from Lighting and Electric Appliances in the Standard and Energy Efficient Settings, as well as the costs both in Mexican Pesos and Euros.

Table 22. Standard / Energy efficient consumption and costs.

	STD SETTING		EE SETTING			
CONCEPT	kWh / MONTH	kWh / YEAR	kWh / MONTH	kWh / YEAR	SAVINGS kWh / YEAR	SAVINGS %
LIGHTING	345.85	4,150.24	63.92	777.64	3,372.60	82%
APPLIANCES	490.50	5,886.03	357.72	4,352.26	1,533.77	26%
TOTAL	**836.36**	**10,036.27**	**421.64**	**5,129.90**	**4,906.37**	**49%**
COST MXN	**3,345.42**	**40,145.08**	**1,686.56**	**20,519.60**	**19,625.48**	**49%**
COST €	**182.51**	**2,190.13**	**92.01**	**1,119.45**	**1,070.68**	**49%**

The projections on Table 23 highlight in red the initial investment for solar panels, solar heater and energy efficient lights selected from the market study. Payback times are highlighted in green respectively. The state electricity company (CFE) offers an interconnection plan in which it can be taken 50% of the electricity needed from the grid, the other 50% can be generated from the solar panels. This strategy is considered for the projections, so the annual savings include the ideal energy efficient case with solar technology. For the solar heater, the average price in the Valley of Mexico of 1 kg of LP gas is 13.50 MXN. The monthly gas consumption for Herradura is around 50 kg per month. Taking this into account, with the solar heater the annual savings will be of 8,100 MXN.

Table 23. Projections.

		SAVINGS						
TECHNOLOGY	INVESTMENT	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	TOTAL
SOLAR PANELS	27,000 MXN	9,812.74 MXN	9,812.74 MXN	9,812.74 MXN	9,812.74 MXN	9,812.74 MXN	9,812.74 MXN	78,501.92 MXN
SOLAR HEATER	8,900 MXN	8,100.00 MXN	8,100.00 MXN	8,100.00 MXN	8,100.00 MXN	8,100.00 MXN	8,100.00 MXN	48,600 MXN
LIGHTING	61, 227.35 MXN	13,490.4 MXN	13,490.4 MXN	13,490.4 MXN	13,490.4 MXN	13,490.4 MXN	13,490.4 MXN	80,942.4 MXN

Simple Calculation

Another approach to calculate payback time is the Simple Calculation or Payback Period formula:

$$PP = \frac{I}{AS}$$

(1)

PP=Payback Period

I=Investment

AS=Annual Savings

The Payback Period formula was used for each field as shown on Table 24.

Table 24. Payback Period.

TECHNOLOGY	CALCULATION	PAYBACK PERIOD
SOLAR PANELS	27,000/9, 812.74	2 YEARS AND 9 MONTHS
SOLAR HEATER	8,900/8,100	1 YEAR AND 1 MONTH
EE LIGHTS	61,227.35/13,490.40	5 YEARS AND 2 MONTHS

For the solar panels, it is considered the initial investment of 27,000 MXN (each Ecovita 280 W panel costs 5,400 MXN) for the 5 panels.

In the case of the solar heater, the model EV-24 has a price of 8,900 MXN, this investment is taken into account for the simple calculation formula. The solar heater will avoid the consumption of 600 kg of LP gas per year and make an annual saving of 8,100 MXN.

The 150 EE lights (86 LEDs, 30 t5 fluorescent tubes, 12 rails, 13 CFL, 5 halogen spots and 4 exterior reflectors) will require an investment of 61, 227.35 MXN. The yearly savings in the EE case are 3, 372.60 kW, this multiplied by 4 MXN (cost per kWh) equals to 13, 490.40 MXN used in the calculation.

4 DISCUSSION

4.1 Overview

This chapter provides a summary discussion on the essential results of this study. Both Herradura's findings and comparison between standard and energy efficient cases along with Picacho's recommendations are presented.

4.2 Standard Case

For the Standard Case, it was determined that the incandescent bulbs and reflectors were inadequate for energy savings and costs. Some of the lights had up to 150 W and in some cases were being replaced every month. Also there were some problems with the circuits creating shortages and energy leaks in some areas. Figure 21 shows the power of different types of lights.

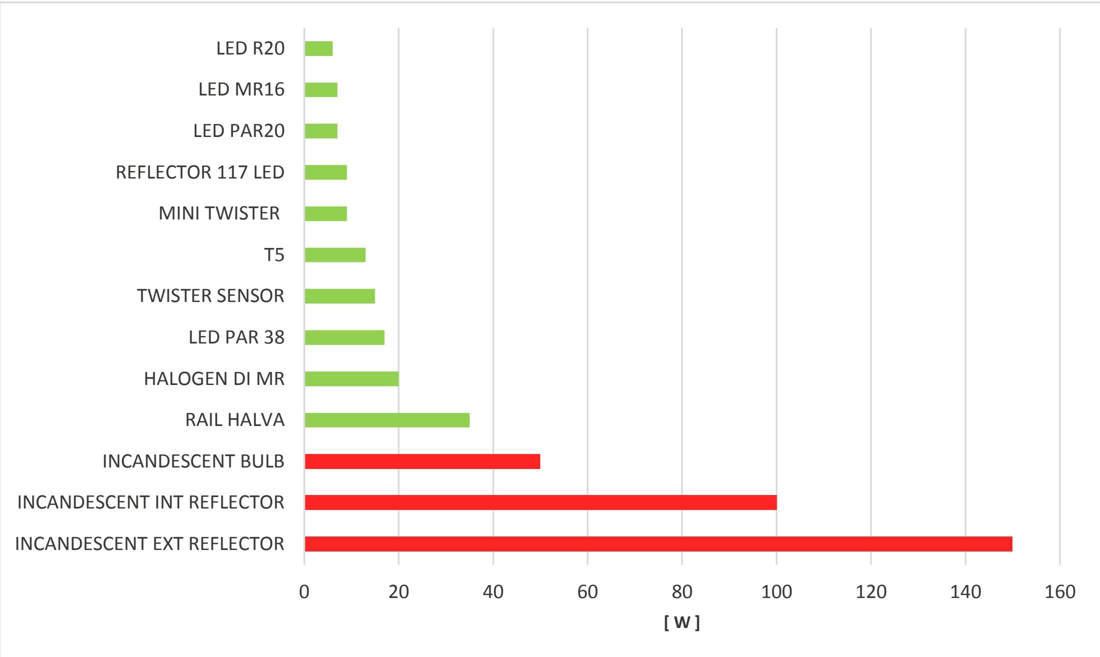


Figure 21. Standard vs EE lights power.

4.3 Standard Case with Solar Technology

The installation of solar panels could reduce the energy consumption up to 50% of the actual consumption. Nevertheless, the energy consumption in this case remains high, product of an obsolete lighting technology and inadequate electric appliances. For the standard case it would be required 8 panels of 290 W to generate half of the demand and the rest would be provided by the grid. As shown on Figure 22, the standard case had a yearly consumption of 10, 000 kWh, even without replacing electric appliances and lights, the consumption can go down as much as 5,000 kWh in an interconnected deal with the CFE.

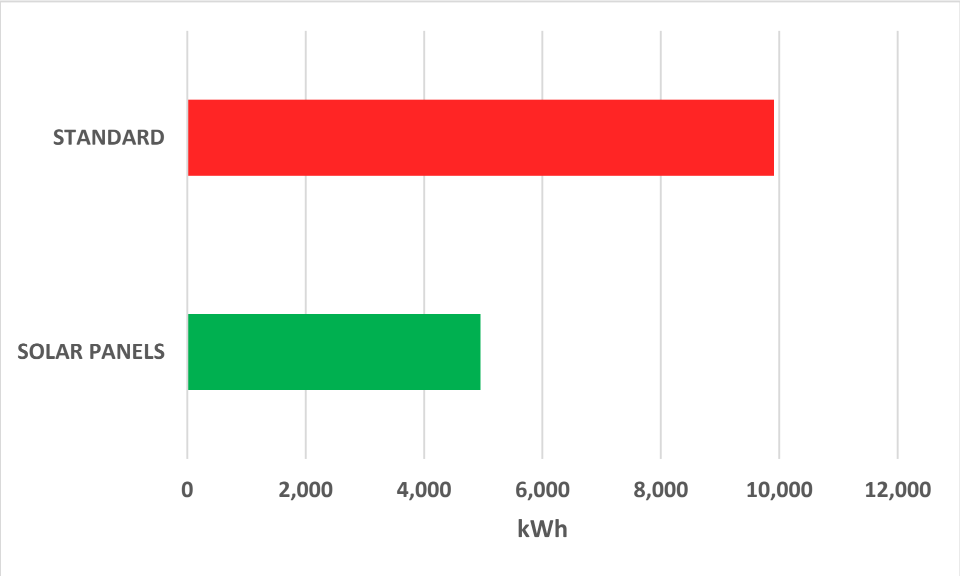


Figure 22. Standard / Solar panels energy reduction.

The solar heater would save 8,100 MXN annually and recover the investment in the second year. The potential energy reduction is halted in this case, despite the solar technology, this standard instance is proven to be ineffective and pointless. Moreover, most engineers and specialist in the field recommend to first optimize energy sources and later calculate the energy demand for solar panels.

4.4 EE Lighting and EE Electric Appliances Case

The replacement of Standard Lighting for EE Lighting showed an energy reduction of 82%. There is a direct relation between costs and technology but in each case it is justified the replacement for EE Lighting. For Lighting, the level with the most energy consumption is the Ground Floor. Figure 23 compares the efficient case with the standard case and displays the monthly energy consumption per levels.

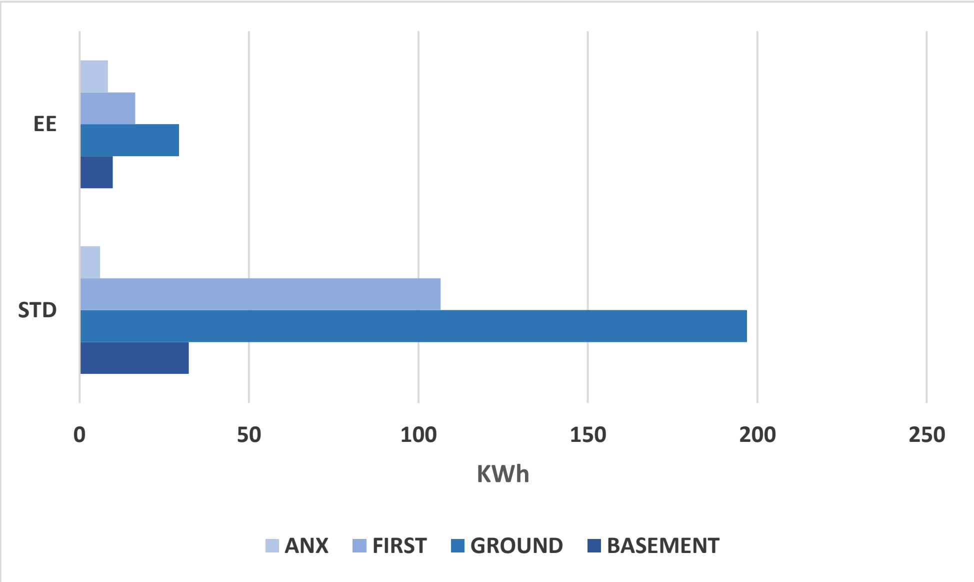


Figure 23. Lighting monthly average consumption per level.

Regarding Electric Appliances, it was consulted with Matouk Family which Electric Appliances they would be willing to replace, they only agreed to replace the water pump, drying machine and washing machine. These replacements would reduce energy consumption by 26%. Compared with the Standard Case, taking both Lighting and Energy Efficient Appliances into account, there is a total of 49% energy reduction.

4.5 Energy Efficient Case with Solar Technology

The combination of Energy Efficient equipment and Solar Technology provides a total energy reduction of 75% compared to the initial Standard case. This evidently is the most convenient case but also the most expensive one in the short term. Nevertheless, solar technology proves to be profitable for high consumption users. For electricity generation in this case, 5 panels of 280 watts would be sufficient to generate 50% of the energy required, receiving the other 50% from the grid. Figure 24 displays the standard case consumption and the EE case with solar technology consumption.

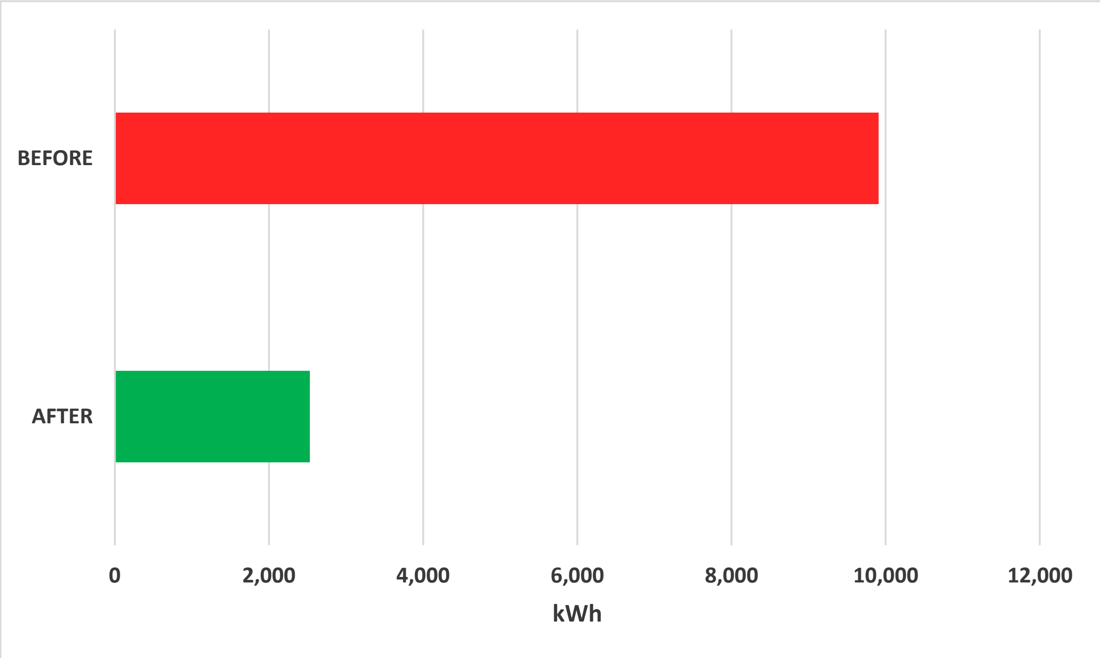


Figure 24. Yearly energy power.

The total investment in the technology and equipment needed is 105, 827 MXN (5,879 €). With the solar panels, ROI is expected in the second year and with lighting and solar heaters ROI is seen after 5 years. Furthermore to this retrofitting, modifications in architectural design should be explored. Improvements in openings, blinds, roof, materials, insulation, etc. should not be ignored.

4.6 Herradura's proposal

The modifications were made according to some solar radiation simulations. These were consulted with the Matouk family. Some are approved, like the open wooden roof along the terrace (to lessen solar incidence) and the façades modifications. This proposal (Figure 25) shows the widening of the Eastern façade and the narrowing of the Southern façade. Also the application of shutters in the East, West and South is presented.

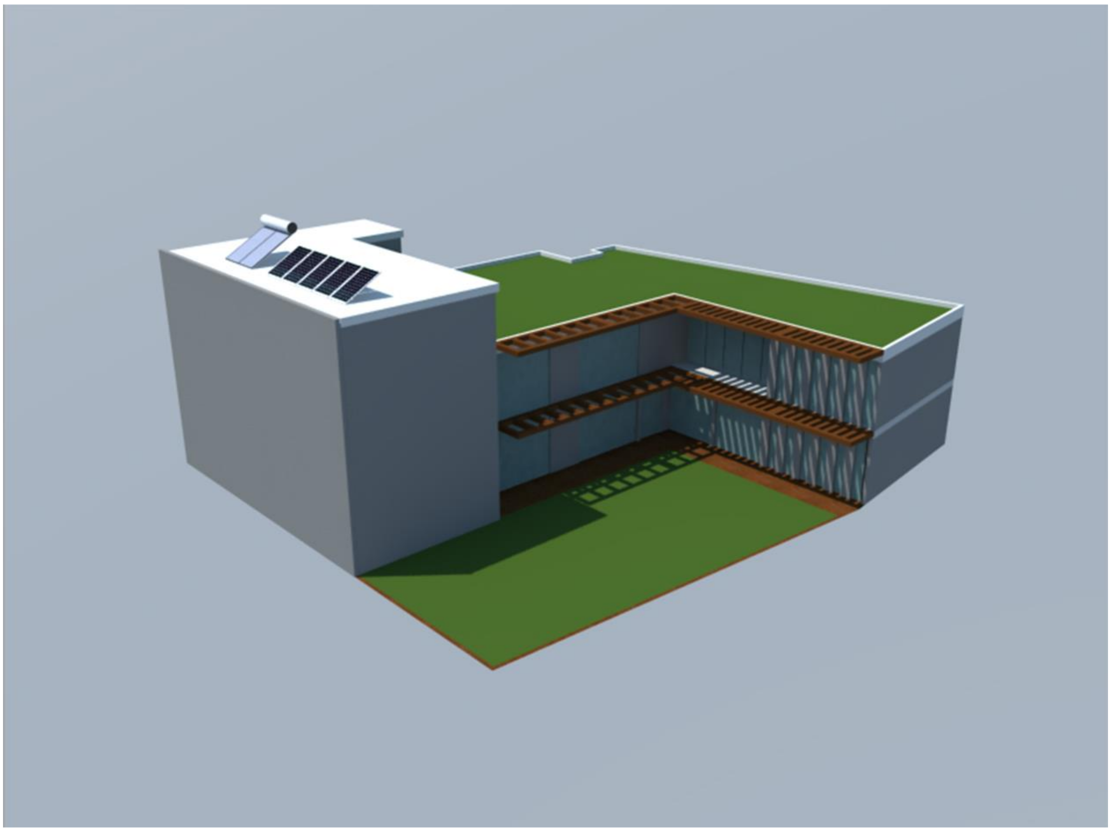


Figure 25. Herradura's residence proposal.

All the lights in the house will be replaced for the ones proposed in the market study, reducing lighting costs by 82%. The users also agreed on replacing the most power consuming electric appliances. On the annex roof, the installation of 5 solar panels for 280 W will generate around 7 kW per day (considering 5 peak sun hours), the rest will be obtained from the grid. Next to them, the solar collector EV-24 for 8 users. The green roof will be replacing the old and faulty insulation on the West and North wing. This natural insulation will lower the interior temperature and will absorb Co2. Some green walls are projected for the Eastern façade.

4.7 Picacho's proposal

Since the Picacho residence is currently inhabited, in this proposal (Figure 26) the solar technology for Picacho is made on estimations considering some information from Herradura which has a very similar program and same housing category. The windows of the West façade were modified to be as wide as possible (30% more transparency than the previous design). The advantages of this residence compared to the Herradura one are the several openings all around the house and the light tones chosen for the house. Both contribute to a good level of interior natural light which reduces considerably artificial lighting.

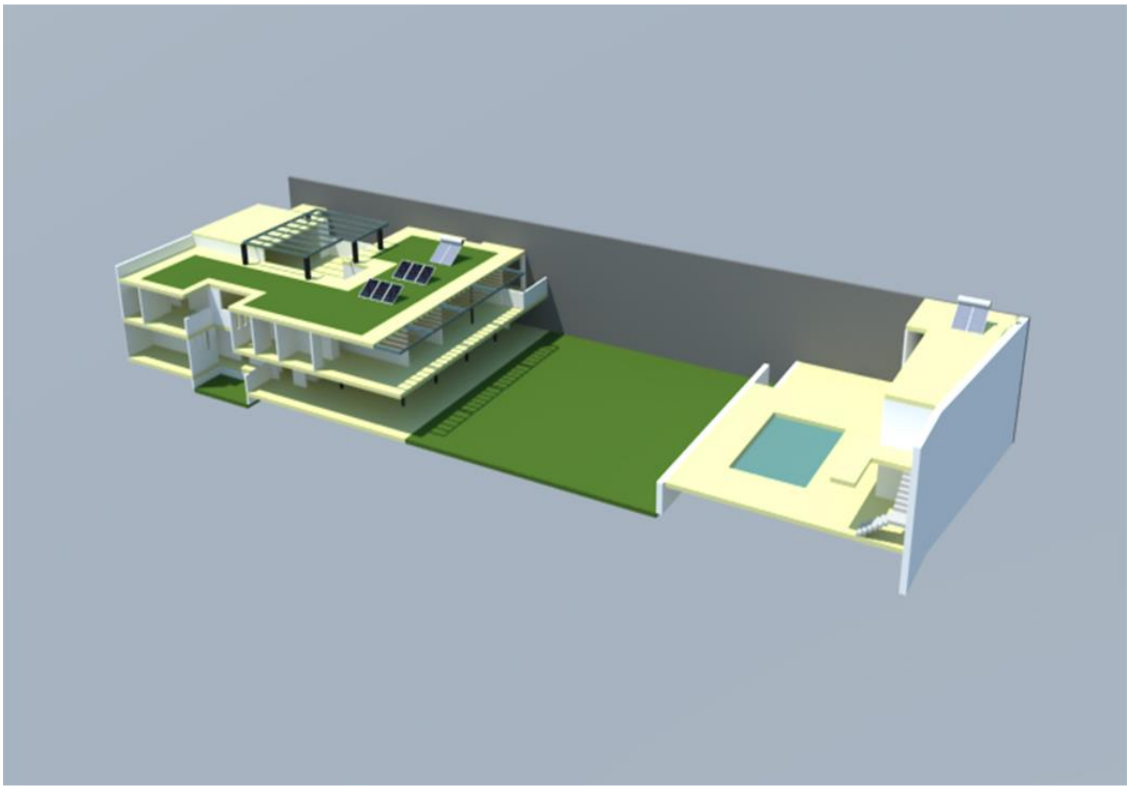


Figure 26. Picacho's residence proposal.

The application of a wooden-glass roof terrace can be seen on the children common area and the Western façade. For water heating, 2 solar collectors are proposed, HP-24 for the annex area; and 1 EV-24 for the main residence. This solar heaters can last up to 25 years. To generate electricity, 6 solar panels of 250 W each, will produce around 7.2 kW daily, leaving the rest of the electricity demand to the State electricity company. This will be an interconnected system, if there is a need for more electricity the residence takes it from the grid, if the panels generate more than needed, the additional energy is given to the grid.

4.8 Optimization guidelines

The study of Herradura's and Picacho's work displayed a whole wave of defects and misuse, but that led to a wide panorama of possible solutions. There are several ways for a household to reduce its energy consumption without having an impact of their way of living. Here are a series of general optimization guidelines that should be taken into account for future luxury projects in the Valley of Mexico and other areas in the country:

- Shading- to avoid mechanical equipment, the use of shutters or blinds are ideal to cool down naturally the residence.
- Façade colour- light colours reflect more solar radiation than dark ones, this should be taken into consideration depending on the context.
- Openings- by general rule, the more openings, the less interior lighting required.
- Cross ventilation- opening windows and doors opposite to each other for several intervals a day can improve the air quality and reduce cooling costs.
- Window operation- during the hottest days, keep the windows closed during the day and open during the night in order to receive cool and dry air.
- Unnecessary electrical appliances and lights- powerful electrical appliances and lights should be avoided, as well as leaving appliances in stand-by mode.
- Shower- taking a bath uses more than 3 times energy and water than taking a 5 minute shower.
- Rainwater tank- rain harvesting could reduce water pump use considerably.
- Right appliances- check the efficiency label of each appliance to make energy savings, do some research before buying.
- Door seals- check constantly that the door of the fridge or freezer closes properly and that there is no air leaks that could lead to high energy costs.
- Position the appliances correctly- choose a cool place for the fridge, avoid hot sources and direct sunlight.
- Dishwashers- modern dishwashers save more energy and water than washing up by hand.

- Natural dry- hang the laundry if possible and avoid the use of drying machines, this can save quite a lot of energy.
- Direct Illumination- avoid indirect illumination where possible to save electricity and reduce heat.
- Roof insulation- a good roof insulation provides a pleasant interior environment and significant savings in air conditioning and ventilation in warm regions.
- Natural barriers- trees can reduce air conditioner costs by up to 30%.
- Electricity company consulting- see alternatives and energy plans available.

Some of the points mentioned can serve as a foundation for energy policies, standards and building codes. It is not sufficient to promote energy certificates or prizes, it would be extremely beneficial for Mexico to establish energy-efficient housing standards like Germany and Austria. One of the challenges Mexico is facing is the proper implementation of the energy reform while keeping the energy demand low. It can be deducted that aggressive energy efficiency measures in the building sector will be critical to conduct the country towards their independent and clean energy goals.

5 CONCLUSION

This chapter is a summary of the most relevant documentation collected over a period of 6 months. Based on the information provided by Matouk Family (Herradura Residence), misuse and inadequate types of lighting and electrical appliances were one of the reasons for high energy consumption and as a consequence, high energy bills. The electricity use per month was similar to the average American household.

The results suggest that a proper lighting strategy needs to be solved a priori construction or renovation status. One of the major miscalculations made during the Picacho's residence construction was the lack of planning due to the inconsistent stages product of economic instability.

Every family has the right to follow their desired lifestyle, yet, if excessive demand can be avoided by applying proper equipment and technology as well as having an adequate management, this will improve their domestic economy and environment.

The use of sensors is proven to be quite effective since there is electricity consumption exclusively when there is somebody present. However, until today, the sensors available in the Mexican market are for either too low or too high wattage.

Solutions that come from design and construction need to be studied, all mechanical and electric equipment should be kept to a minimum. Even "smart" systems have demonstrated to be not that smart or not smart at all. The human variable will always collide with any attempt to systematize indoor conditions collectively.

Due to the high temperatures generated in residences particularly those with the most exposure in warm places throughout the country, it is necessary to contemplate shading conditions to make them more habitable and to cancel the use of air conditioners keeping in mind natural ventilation too.

In the solar energy context, it would be favourable for the government to establish more aggressive energy codes and policies, taking advantage of the enormous solar radiation in the country. More incentives regarding energy efficient housing are needed. This is mostly a political issue, but a political issue that can be driven with scientific facts towards a common solution.

The financial analysis showed how most investments in energy efficient technologies get pay back after only a few years, even while considering inflation. Although some of the equipment is considered expensive, it is targeted for the people who can easily afford it.

Further research

Further improvements need to be considered and some design strategies need to be revised in the near future. In addition, it is important to indicate that architectural design does influence considerably the energy consumption of a certain building. This was one of the main setbacks in Herradura's residence where the openings were not optimal, increasing the need for artificial lighting.

Since the Valley of Mexico has a temperate climate, additional analysis in areas with cooling and heating loads is advised. Moreover, water is one of the major concerns in the country, and this analysis does not dissect it, but it should not be ignored for future accounts.

Due to the considerable distance between the case studies and the university, this study was produced with data, figures and computer aided design. For subsequent research a lengthier on-site approach with sensors and other measuring instruments is recommended.

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APPENDIX

A. Figures

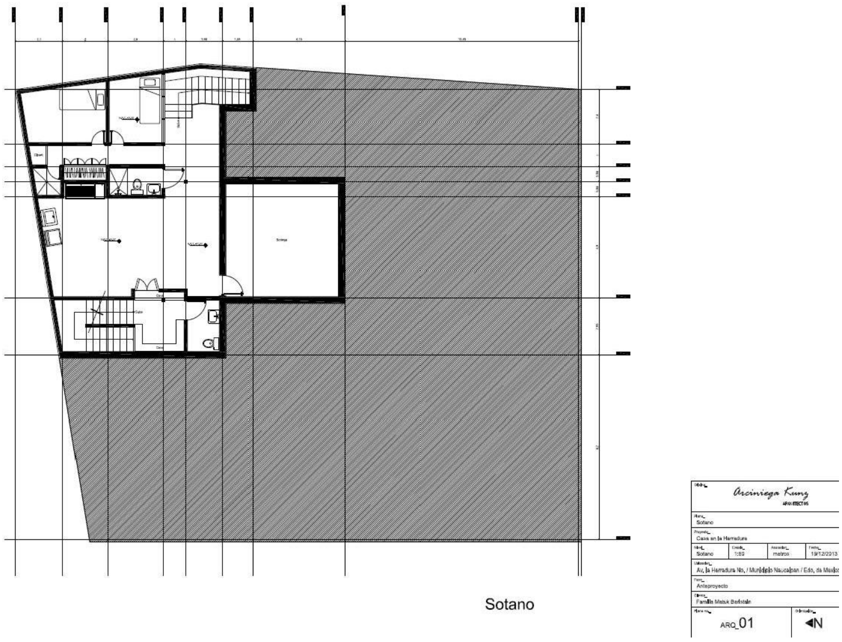


Figure A1. Herradura's residence Basement.

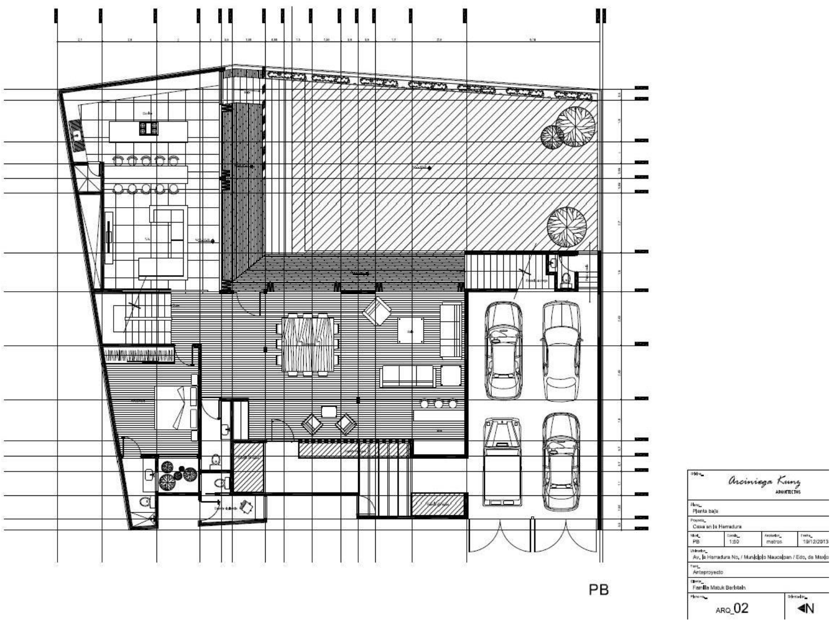


Figure A2. Herradura's residence Ground Level.

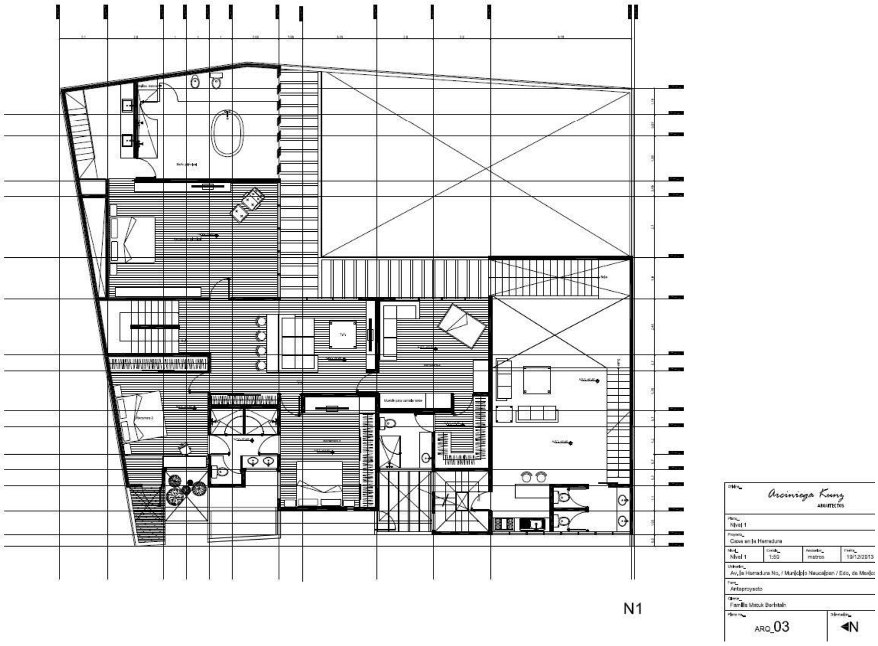


Figure A3. Herradura's residence First Level.

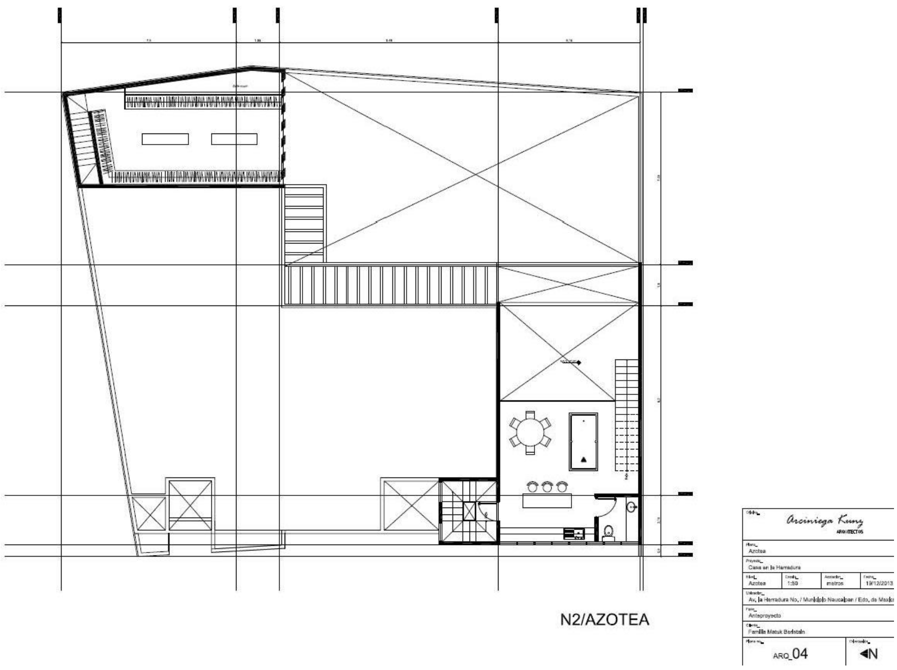


Figure A4. Herradura's residence Second Level.

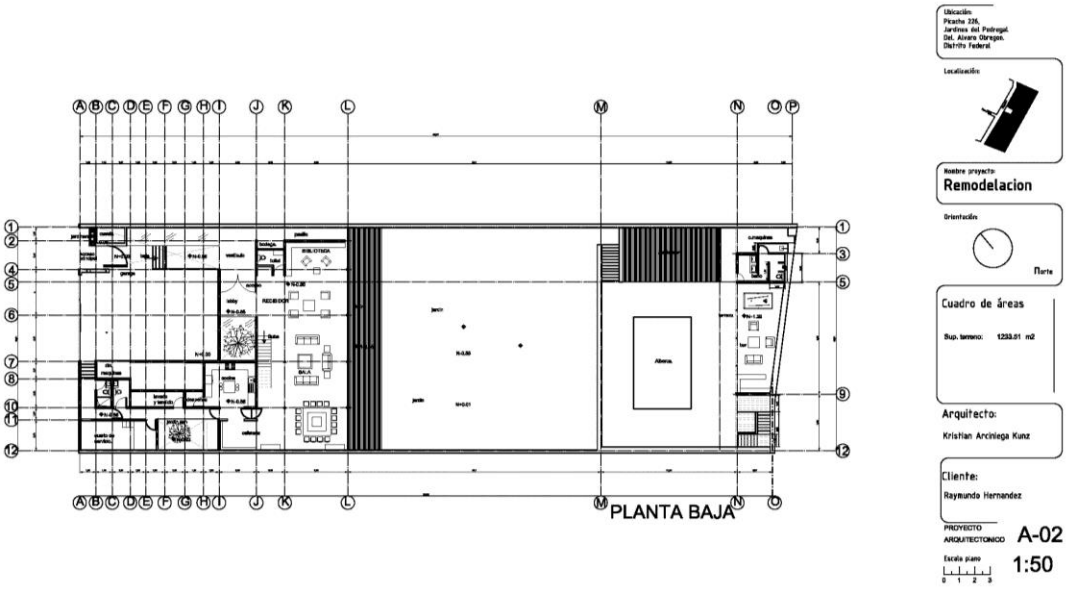


Figure A5. Picacho's residence Basement.

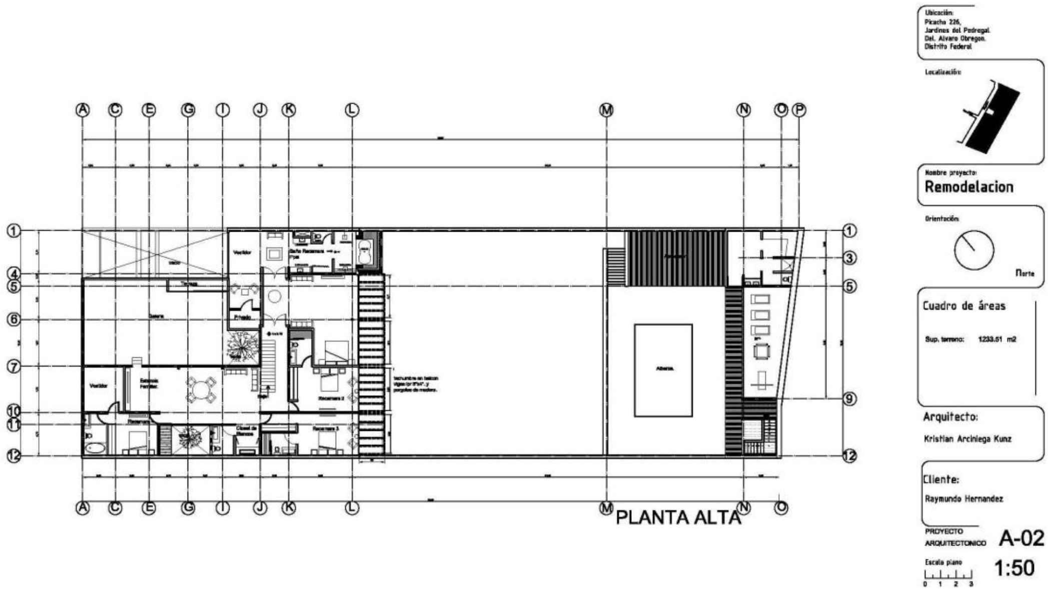


Figure A6. Picacho's residence Ground Level.

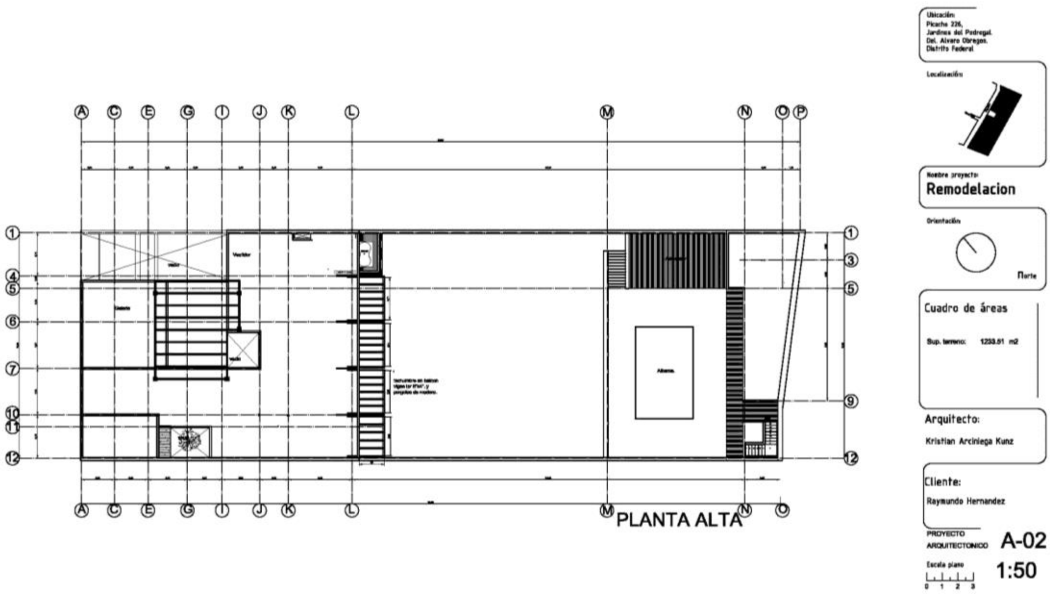


Figure A7. Picacho's residence First Level.

Figure A8. Herradura's residence West and South façades.

Figure A9. Herradura's residence garden and Annex.

Figure A10. Herradura's residence garden view.

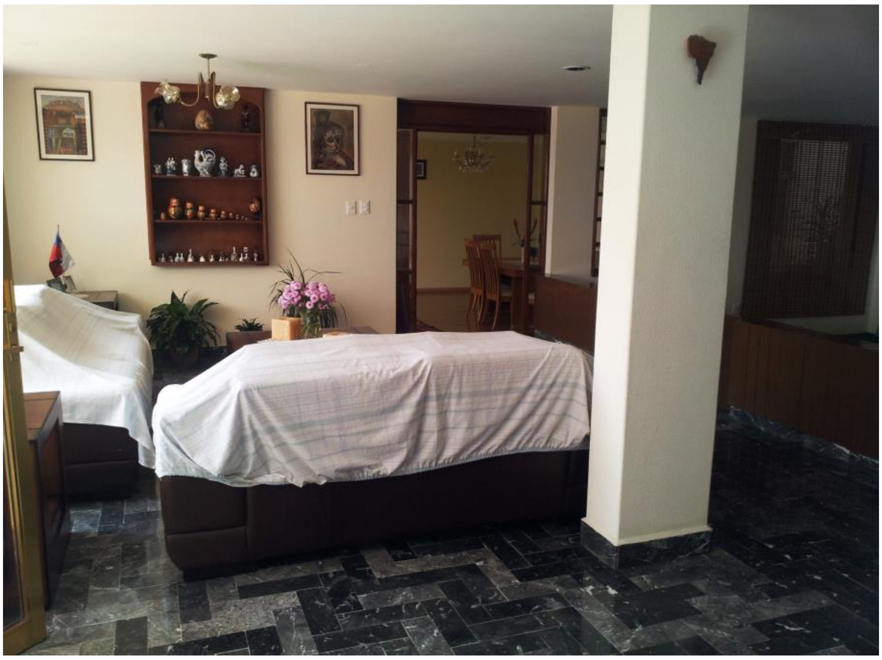


Figure A11. Herradura's residence Living Room.

Figure A12. Picacho's residence Ground Level.

Figure A13. Picacho's residence East facade.

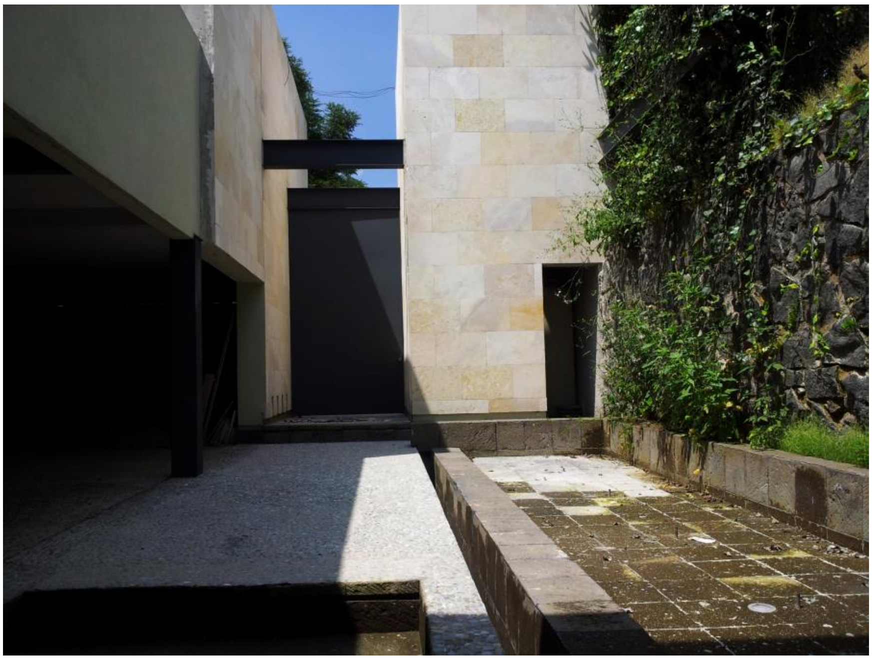


Figure A14. Picacho's residence vestibule.

Figure A15. Picacho's residence West terrace.

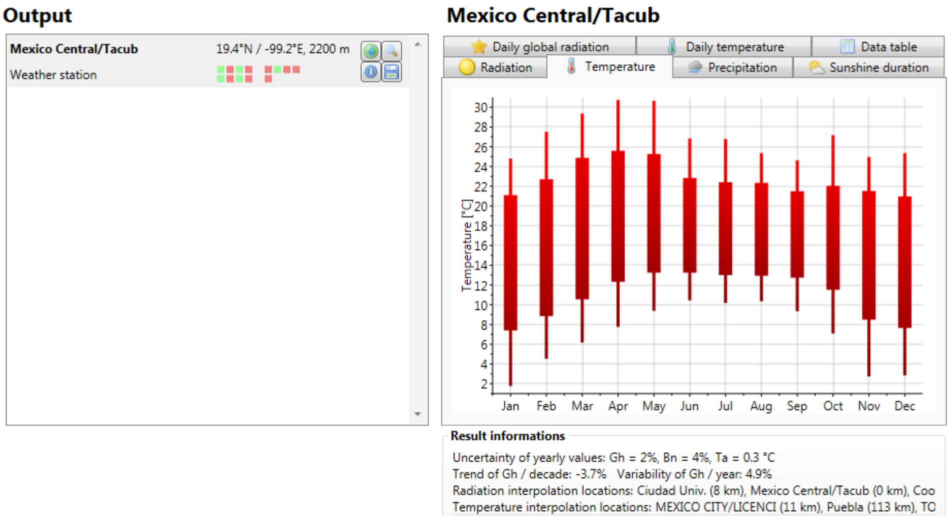


Figure A16. Mexico City yearly temperature.

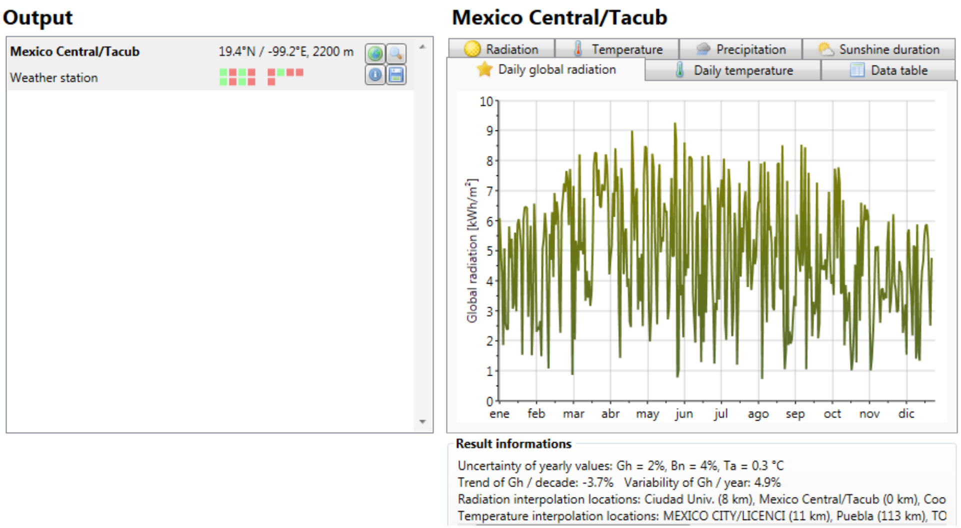


Figure A17. Mexico City yearly global radiation.

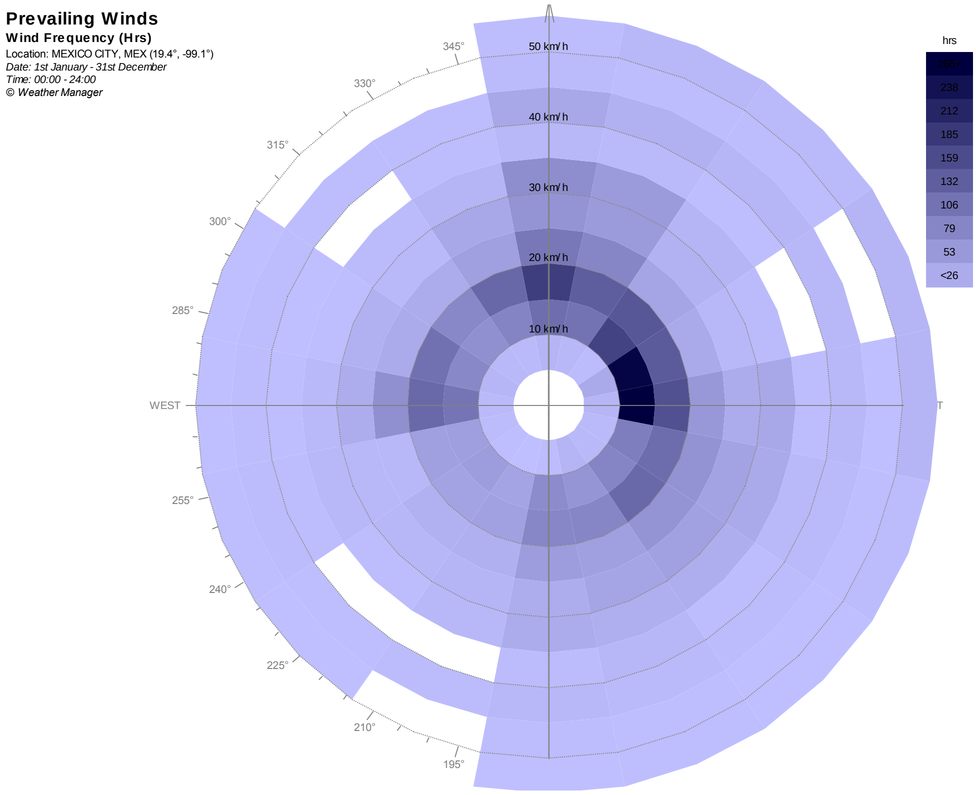
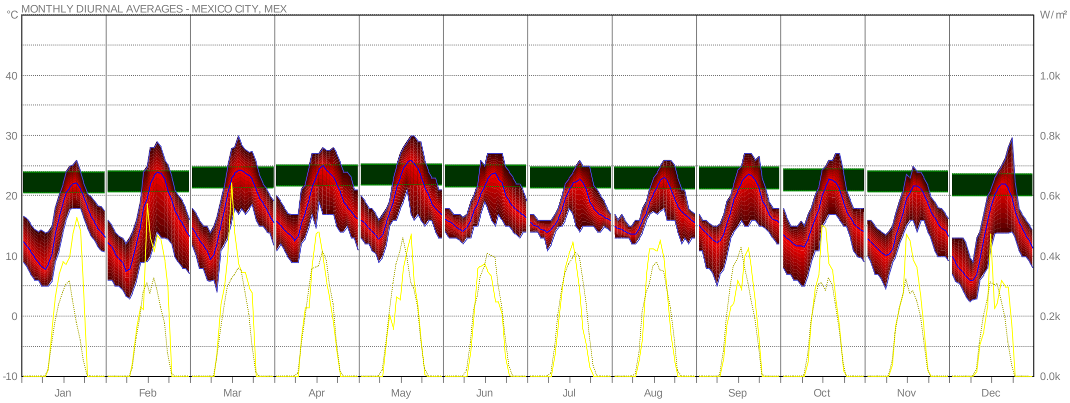


Figure A18. Valley of Mexico prevailing winds.



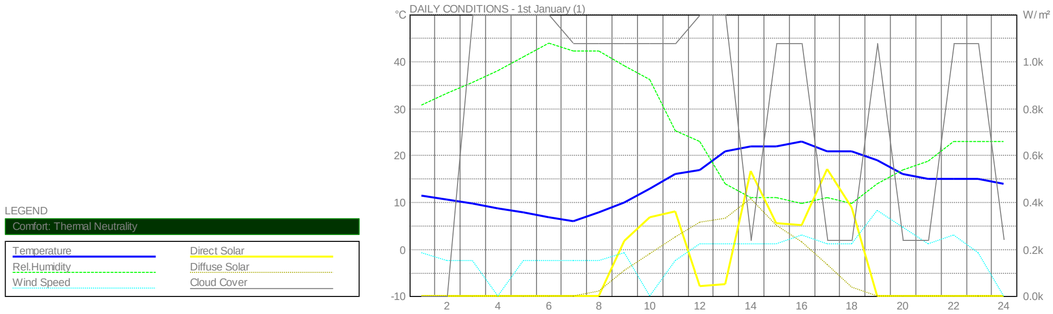


Figure A19. Mexico City monthly diurnal averages and daily conditions.

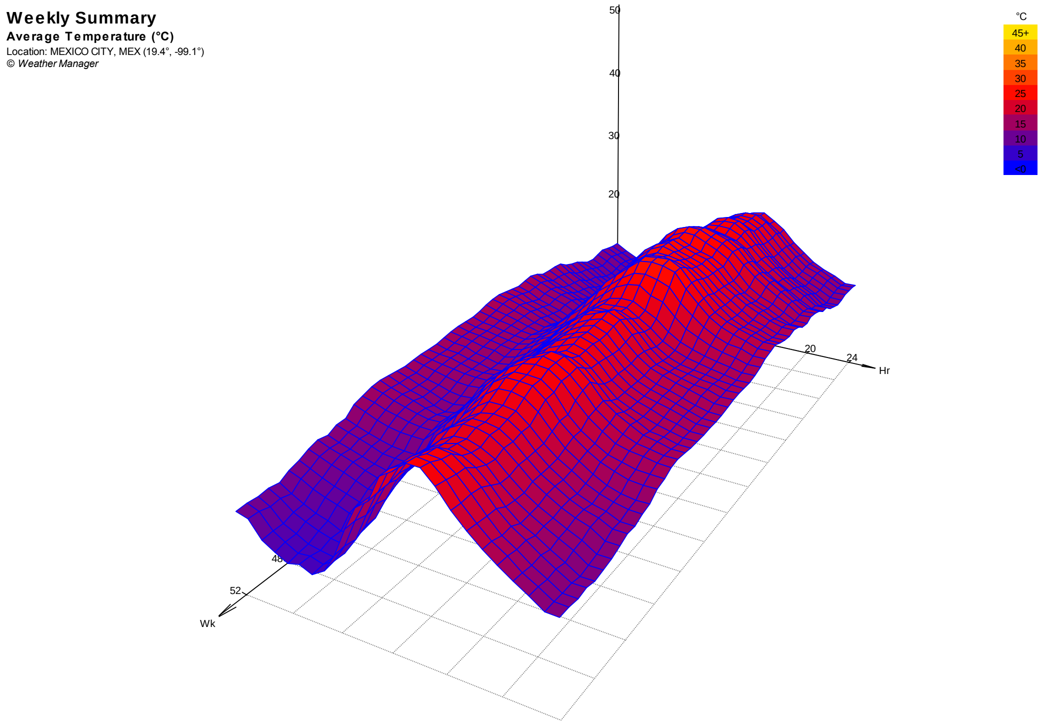


Figure A20. Mexico City weekly average temperature.