Assignment:

Capstone

Course:

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Abstract

The world's demographic index is rapidly increasing. Every country's evolvement is affecting one another, especially the environment and the world. This is not always affected by every single country, since some countries are more advanced in technology and resources than others, but most of the world is depending on high amounts of fossil fuels to self-sustain cities and countries. As such, by now it is well informed that the world is being constantly affected on the actions people aren't acknowledging, such as living a great lifestyle without the affection and knowledge that the world is coming apart. Global warming and climate change are subjects that have progressively been enduring their importance around the world.

The most challenging part of this progression is that it has not been accepted around the world. Some countries are not taking climate change seriously and it the world depends on it. For instance, one of the main branches of pollution and the burning of fossil fuels is construction. The carbon footprint of a building is higher than most consuming activities. According to the United Nations Environment Program (UNEP) 'Buildings and their construction together account for 36 percent of global energy use and 39 percent of energy related carbon dioxide emissions annually.' (https://archive.curbed.com/2019/9/19/20874234/buildings-carbon-emissions-climate-change)

However, this is being revolutionized in some countries in the world such as Sweden, Denmark, and China, where the majority of buildings are net zero, have already applied certain regulations to their buildings and the way they are designed and built. On the other hand, countries like Peru, Argentina, or Chile have the least number of buildings designed and built to reach the net zero goal. The regulations described above mention the LEED, EDGE, BREAM certifications that are

given to certain buildings that achieve certain sustainable goals, and these buildings are mainly designed to be self-sustainable, withdrawing energy from renewable sources such as solar panels, hydropower, wind energy, geothermal energy, and biogas.

In addition, Peru is a country that has slowly but surely gotten into the business of sustainable buildings and renewable energy, where companies have now introduced the construction of green buildings running on renewable energy, or simply buildings that are sustainable to a certain degree.

1. Introduction

1.1. Problem Statement.

Worldwide our environment is hurting. At this point, anything contributing to reversing the effects of globalwarming is essential. According to the Global Builders website: "Construction projects worsen climate change. The sector accounts for 25 to 40 percent of the world's total carbon emissions. Estimates suggest that emissions from commercial buildings can grow up to 1.8 percent in 2030." (Environmental Impact of Construction addressed by Global Builders)

These facts cover both the construction process and the purpose of the building. Sustainable green buildings have become the trend nowadays. In Peru, there has been minimal action taken to mitigate climate change. Sustainable green buildings could be one of the largest positive factors to revert the negative impacts. "One of the most important types of benefit green buildings offer is to our climate andthe natural environment. Green buildings can not only reduce or eliminate negative impacts on the environment, by using less water, energy or natural resources, but theycan - in many cases - have a positive impact on the environment (at the building or cityscales) by generating their own energy or increasing biodiversity." (The benefits of green buildings.)

According to the website Statista, Peru is one of the Latin American and Caribbean countries with the highest ambient particulate matter pollution exposure. (https://www.statista.com/statistics/869191/particulate-matter-pollution-concentration-latin-america-country/).

The high ambient particulate matter pollution exposure is mainly because of the air pollution

from transport, the poor care of the vegetation, infrastructure, construction industries, and more. Focusing more on the construction firms, most buildings in Peru are non-sustainable. Nevertheless, some of these companies have taken some action to produce sustainable buildings in the future.

How does the implementation of various independent green energy types affect energy costs and money in conventional vs. sustainable buildings? This study aims to analyze results from a pair of buildings, a conventional and a sustainable building, and compare the results of solar energy and water-saving technology implementation throughout the building.

1.2. Site Analysis

The study area is based in Lima, Peru. The main objective is to record and study values from different conventional and sustainable buildings. This is based on two buildings that have implemented green energy and conventional energy, respectively. The study is based in Lima rather than any other city or place in Peru because Lima is the capital of the country, where most of the infrastructure takes place. 90% of the mass production of buildings takes place in Lima. There have been several interventions for green buildings in Peru, and these only seem to appear in the Capital city. Some examples of green sustainable buildings and LEED-certified buildings in Lima are the Westin Hotel, the LEURO business center, the UTEC University, and Roche laboratories.

Apart from the interventions of the different types of buildings in Lima, the climate in the city is crucial to consider the implementation of different sustainable energy in buildings. Lima is well known to have a very mild climate, and this means that it does not reach very hot

temperatures in summer nor very cold temperatures in winter. The construction process is very simple compared to cities that reach high temperatures (like Tucson, Arizona) or very cold temperatures (like Madrid, Spain); there is no need for a special type of construction.

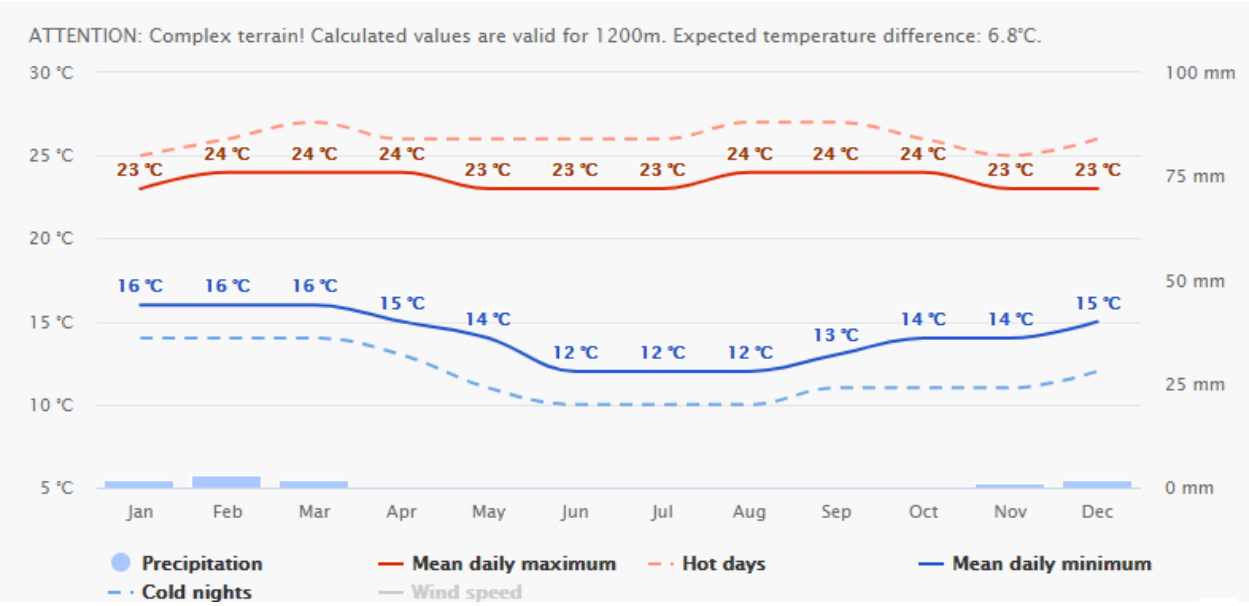


Figure 1.1 Figure showing data collected from precipitation and temperatures in Lima, Peru

Source: (https://weatherspark.com/y/20441/Average-Weather-in-Lima-Peru-Year-Round)

Apart from the city's temperature range, sunlight hours and precipitation are also measured in the city. There is no precipitation throughout the vast majority of the year, but the air is very humid. Lima is usually sunny all year round. Overcast climate often happens around September and October.

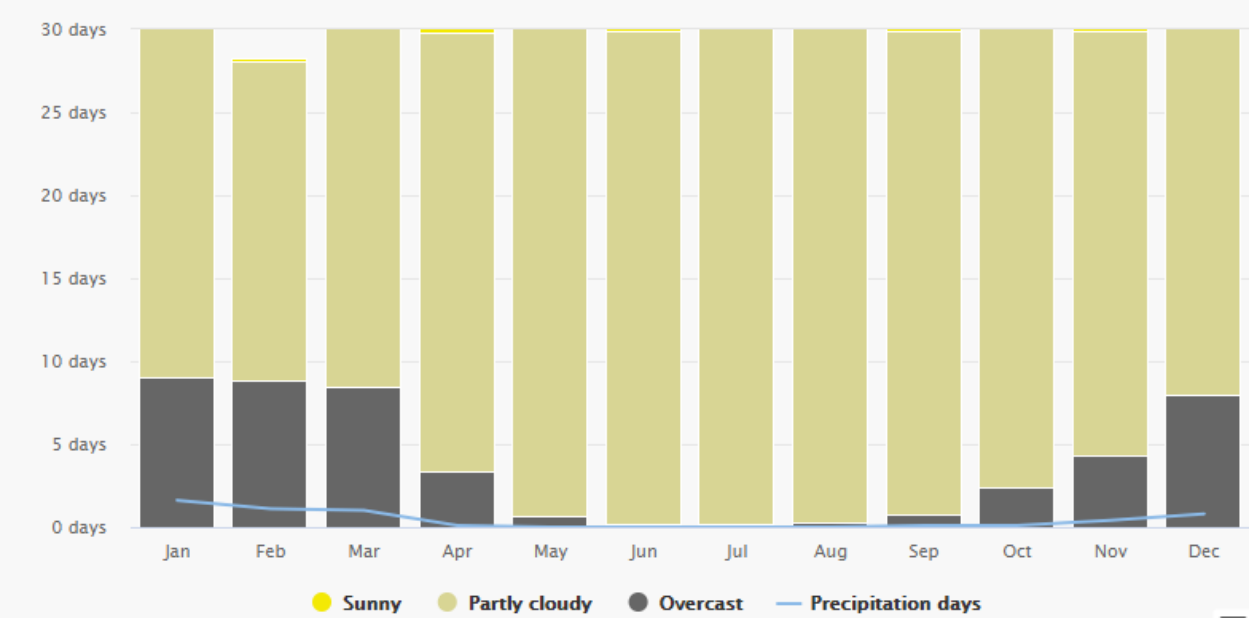


Figure 1.2 showing data collected from Sunny and Cloudy days in Lima, Peru

Source: (https://weatherspark.com/y/20441/Average-Weather-in-Lima-Peru-Year-Round)

1.3. Hypothesis

This study focuses on how implementing various independent green energy types affects energy costs and money in conventional vs. sustainable buildings. Sustainable energy tends to be expensive at the start because of the manufacture and the costs. However, as time passes, the cost throughout the years tends to stay in a linear correlation. On the contrary, if we consider conventional energy implemented, the process would be the opposite- energy costs would be very low at first. However, it would rise exponentially compared to sustainable energy. The hypothesis for this capstone would be that costs will rise for both types of energy, and there would not be a notable difference between the two, but at long term, these costs would have different behaviors. Sustainable energy costs would stay steady at a linear growth whereas the electrical energy costs would rise exponentially.

1.4. Objective

The main objective of this study is to analyze two different types of buildings in Lima, Peru. These two buildings were homes, and had the same terrain, apartment areas, and the same method of construction: the only notable difference between the two was the type of energy used. One of the buildings is sustainable, and the other one runs on electrical energy. The previous analysis of the different types of buildings in the area that will be studied is crucial. The type and purpose of buildings make a statement on whether it would be important to make sustainable buildings rather than conventional buildings, regarding its different energy impacts on solar energy and water-saving techniques, to conclude on the economic impacts on users. All of this analysis would be needed to respond to the first implied research question: how does the implementation of various independent green energy types affect energy costs and money in conventional vs. sustainable buildings?

2. Literature Review

There were four primary sources of literature reviews chosen. The main goal of the research is to find out the importance of sustainability in building designs to mitigate the effects of global warming (ück, Harald, et al.,2018). One of the most important findings was implementing solar energy (Miranda, L., Valdivia, R. et al., 2014). Also, green design is directly related to sustainable construction, which targets minimizing natural consumption and the resulting impact on its environment (Kibert, C. J. (2016). Finally, this shows that one of the main factors affecting sustainable green buildings is the country’s development. The less developed countries suffer from what they do not have, and in the making of green and sustainable buildings, you need certain materials and specific technology (Hwang, Bon-Gang,

& Tan, Jac See. (2012).

2.1. Solar Energy and Solar panels

Solar energy is one of the most popular renewable energy types globally, and one of the most used around the world. This is because of its efficiency and simplicity volume wise. Solar energy is the radiation from the sun that is absorbed by the solar panels, which transforms the thermal energy to kinetic energy, therefore generating electricity. The most common type of solar panels are the flat plate collectors which are used for the absorbance of the heat from the sun. These plates are made of a blackened metal plate that is covered by two sheets of glass, which would absorb the sunlight. Some advantages of solar energy to the environment are: the reduction of air pollution, the reduction of water usage, reduces dependence on non-renewable energy sources, and helps fight climate change.

Source: (https://www.vivintsolar.com/learning-center/benefits-of-solar-energy-to-the-environment)

Image showing solar panels implemented in a building

Source: (https://panthernow.com/2011/10/21/solar-panels-proposed-for-all-buildings/)

2.2. Water Saving Techniques

Water saving techniques are probably one of the most common ways buildings conserve water and conserve energy. Its efficient measures can reduce water use in a conventional building by over 30%. This sustainable technique is a cheaper variant to other renewable energy types such as Solar power or Hydropower (from dams) because it doesn't need a complicated installation and maintenance. Also, water does not need to be potable for the various uses in a building, but most buildings use potable water anyway. Two examples of this is toilet flushing water and irrigation. Therefore non-potable water would be made from water saving techniques called greywater and rainwater harvesting.

2.2.1 Greywater

Greywater is described as the reuse of resultant water from showering, sinks, baths and washing machines. It may not always be considered as clean, but with simple filtration the pollutants can be filtered out. When weighing the pros and cons for greywater, the only downfall would be that it cannot be stored for future usage, unlike rainwater.

2.2.2 Rainwater

Rainwater is the accumulated or gathered water from roofs or paved areas that comes from a heavy day of raining. Rainwater is not common in cities like Lima (Peru) due to its geographical location being a desert. This means that its uncommon appearances would definitely need a storage system for it to be saved for future uses. Source: (https://sustainability.williams.edu/green-building-basics/water-conservation/)

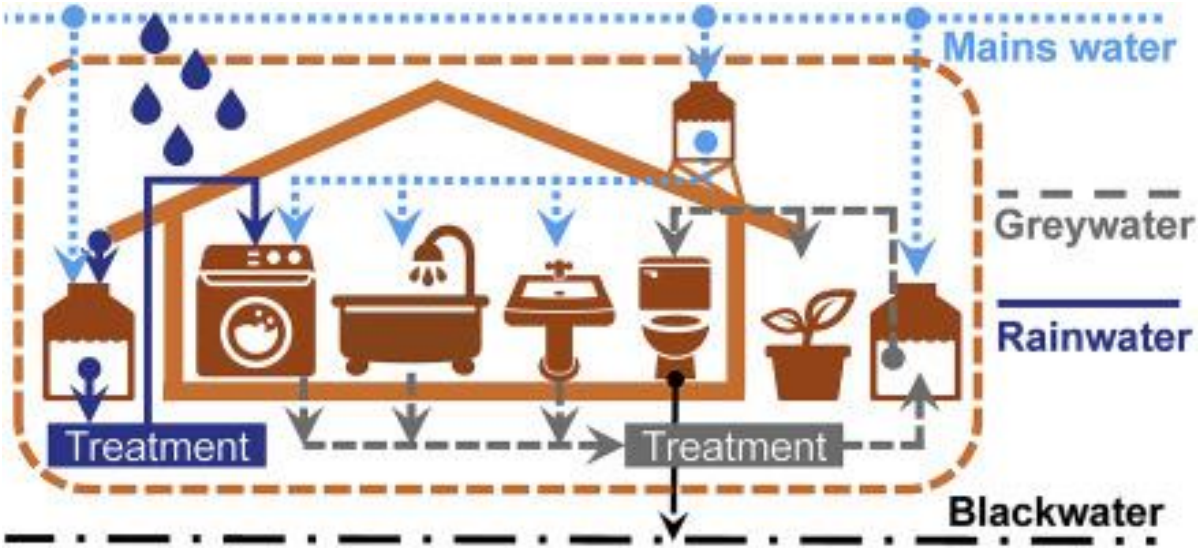


Diagram showing the process of water saving techniques such as rainwater and greywater

Source: (https://www.sciencedirect.com/science/article/abs/pii/S095965261631798X)

3. Data Collection

3.1. Data and Measures

This research project consists of studying renewable energy use in buildings in Lima, Peru. The data collection methods are online resources. There was a topic selection among the renewable energy family, solar power, and fossil fuel-generated electric power for this data collection. Data from research on conventional and sustainable buildings called ‘towards sustainable building in climate change scenarios’ will be evaluated for the data and measures aspect. The data set refers to the costs across years for solar energy on sustainable buildings vs. conventional builds.

3.2. Methods

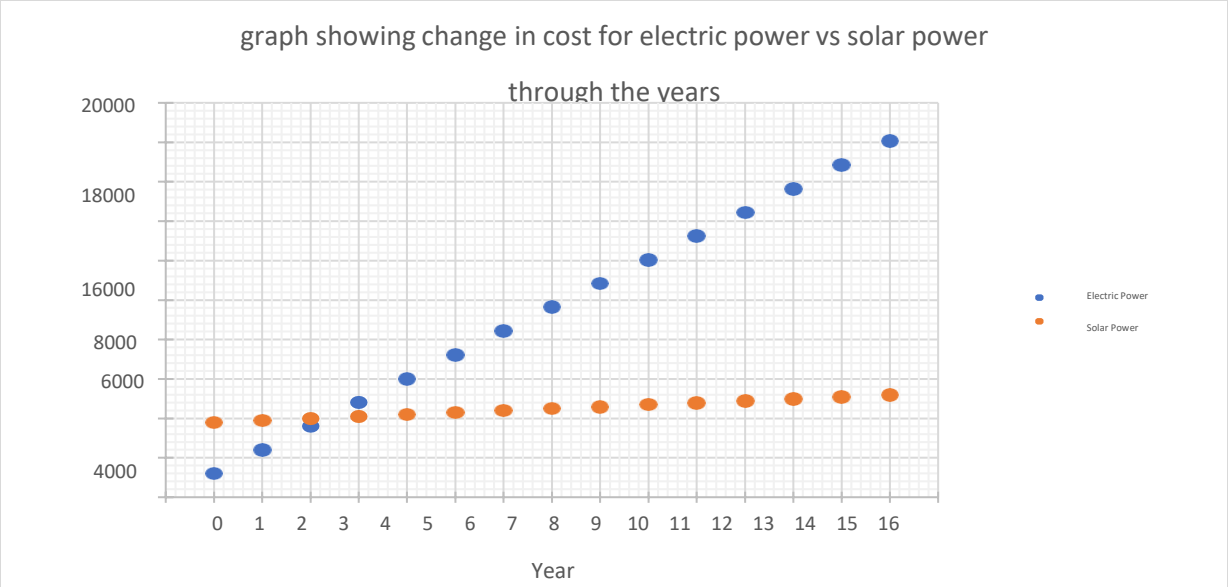
First, I looked for a relationship between the conventional electricity costs and solar costs

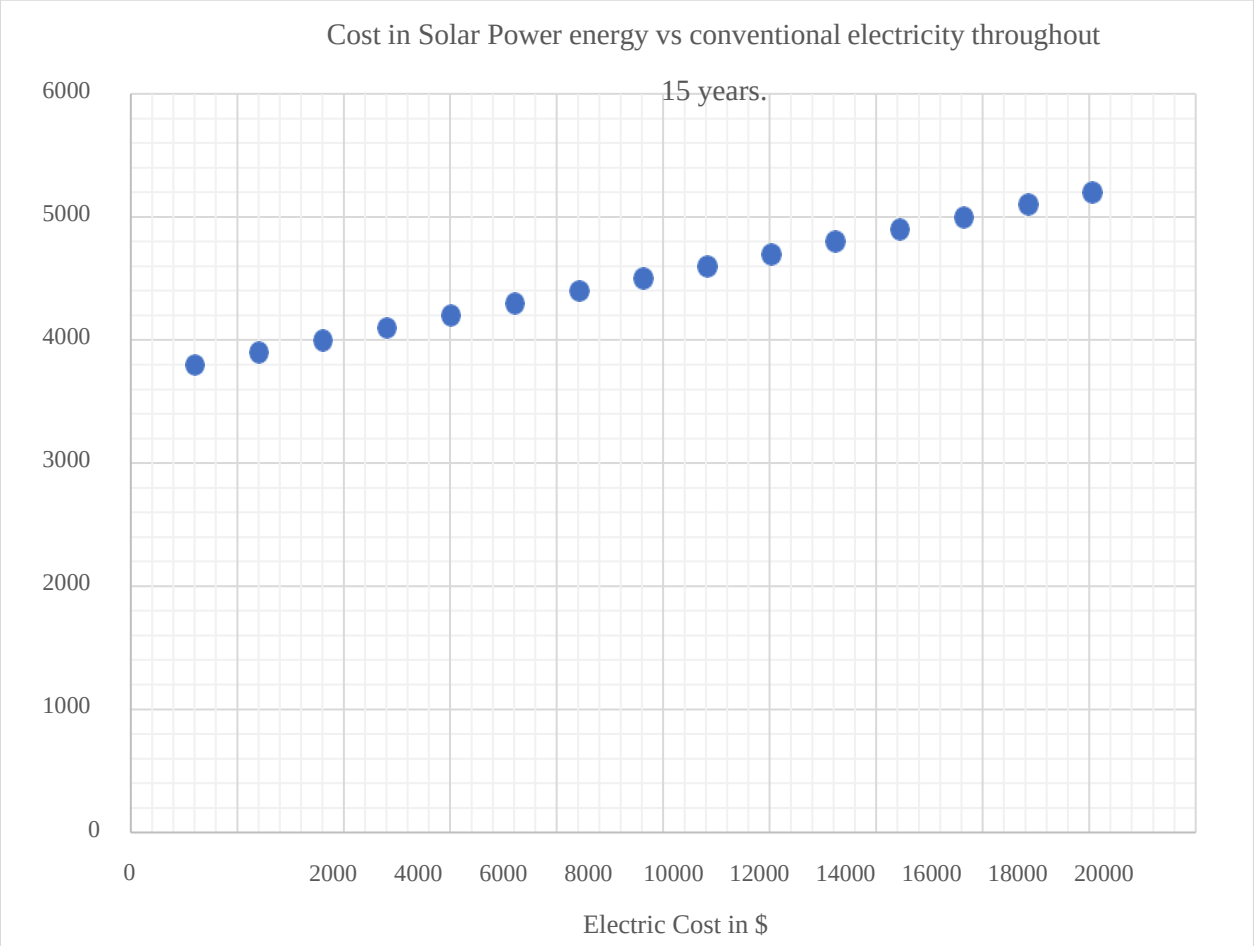
over 15 years.

YEAR	ELECTRIC COST DOLLARS	SOLAR COST DOLLARS
1	1203.84	3800
2	2407.68	3900
3	3611.52	4000
4	4815.36	4100
5	6019.2	4200
6	7223.04	4300
7	8426.88	4400
8	9630.72	4500
9	10834.56	4600
10	12038.4	4700
11	13242.24	4800
12	14446.08	4900
13	15649.92	5000
14	16853.76	5100
15	18057.6	5200

Table 1.1 shows the change in cost throughout the years between solar-powered energy and conventional energy in two buildings, one a sustainable green building and the other a green building, respectively.

Source: (https://www.cies.org.pe/sites/default/files/investigaciones/edicion_final_estudio_construccion_sostenible.pdf)


graph showing change in cost for electric power vs solar power through the years
20000
18000
16000
8000
6000
4000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Year
Electric Power
Solar Power


Cost in Solar Power energy vs conventional electricity throughout 15 years.
6000
5000
4000
3000
2000
1000
0
0 2000 4000 6000 8000 10000 12000 14000 16000 18000 20000
Electric Cost in $

Then, the water savings will be measured. Water-saving techniques are implemented in sustainable housing by using different mechanisms like changing the appliances a bathroom could use, like the toilet would be a dual toilet that works differently than a conventional one, or the faucet/tap would have a different design as well. All of this is implemented to ensure the cost benefit impact of water consumption on the environment, and also the final costs of these would be evaluated.

annual consumption of water per household		
	annual conventional	annual sustainable
consumption	62.05 m3 per person per year	43.44 m3 per person per year
cost (S/. 3.12 x m3)	S/. 193.59	S/. 135.53
savings	0%	30%

Table 1.2 shows the measures for normal water consumption in a household per person per year and compares water consumption in a sustainable household per person per year.

Source: (https://www.cies.org.pe/sites/default/files/investigaciones/edicion_final_estudio_construccion_sostenible.pdf)

Before showing table 1.3, some terms must be clarified. In Peru, billing does not differentiate the origin of the consumption, such as toilets, showers, laundry, or garden watering. Through different measures or modifications, such as the use of saving taps (level 1), use of modern household equipment - washing machines, dishwashers, etc. - (level 2), use of rainwater (level 3) or the recycling of gray water (level 4), a considerable saving potential is achieved without influencing the quality of the service.

potential water consumption savings (liters per person per year)					
	Today	level 1:	level 2:	level 3:	level 4:
	normal consumption	conventional technique	usage of additional appliances	additional usage of rainwater	grey water recycling
personal use	46 (100%)	35 (75%)	23 (50%)	23 (50%)	23 (50%)
toilet	40 (100%)	30 (70%)	20 (50%)	4 (10%)	0 (0%)
clothing	17 (100%)	15 (90%)	13 (75%)	4 (25%)	2 (10%)
dishwashing	8 (100%)	7 (90%)	6 (75%)	6 (75%)	6 (75%)
cooking	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)
cleaning	6 (100%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)
gardening	3 (100%)	3 (100%)	3 (100%)	1 (25%)	0 (0%)

Table 1.3 showing the measures for different water-saving techniques that could be implemented in sustainable housing

Source: (https://www.cies.org.pe/sites/default/files/investigaciones/edicion_final_estudio_construccion_sostenible.pdf)

3.3. Case Study Examples

3.3.1 Hacia la Construcción Sostenible en Escenarios de Cambio Climático

The study ‘Hacia la Construcción Sostenible en Escenarios de Cambio Climatico’ or ‘Towards Sustainable Construction in Climate Change Scenarios’ is about an investigation that Peruvian architects developed about the different renewable energy types developed in Peru, and how these were implemented in buildings. As mentioned in the abstract, the construction and development of buildings take a very notable portion of the carbon emissions worldwide, and these causations of the carbon emissions are rapidly tearing down the environment.

This group of architects decided to investigate about the causations and consequences of these conventional buildings in the environment and using data about different types of energy compared to sustainable energy, withdraw conclusions about how the sustainable energy could potentially be the solution to have a net zero building. However, they not only investigated about the types of sustainable energy but also ways in which buildings could evolve from being a conventional building running on normal electricity, to a sustainable building utilizing different sustainable methods of the reduction of energy usage, to lower costs. This method would be used if a economic background would be the case.

3.3.2. Comparison between two buildings: San Fernando and Grimaldo del Solar

The buildings San Fernando and Grimaldo del Solar, are two buildings that have been designed, developed and constructed by the same group of architects and the same construction company

in Lima, Peru. The construction company is VyV, and the group of architects are Reusche & Reyna. These two buildings were designed and constructed with the same building materials and also similarly, the same amount of housing units, but the main difference is that one of them is sustainable, and the other one is conventional, Grimaldo del Solar, that has acquired a v4 LEED certification and San Fernando which runs in normal electricity, respectively.

In the architectural construction design, the two buildings have conventional construction systems with reinforced concrete columns, plates, and beams, together with solid reinforced concrete slabs to achieve a load-bearing structure for seismic and gravity loads. In addition, the façade design for these two buildings also has similar material design, since they both were designed by the same architect, the technique is very comparable. They have 8 and 9 floors, and also share the same common areas such as a double height lobby, gym, barbecue area, pool, conference rooms and more.

The reason on why it was decided to talk about a case of two existing buildings, is because the information shared from the data and measures above matches quite literally with the findings from the savings of these buildings overall. The building Grimaldo del Solar, gathers different water saving techniques, also has the implementation of LED lights in every single housing unit, the different architectural finishes of the facade and the interior of the housing units and building allows it to be temperature friendly, where in summer, the heat is not absorbed in walls or flooring and in winter, the cold would not go through windows or floors. There is not a default installing of air conditioning in this building in housing units, but the owners that wish for air conditioning could potentially install them if they would want to.

Image showing the façade for Grimaldo del Solar (Green Building)

Source: (https://vyv.pe/)

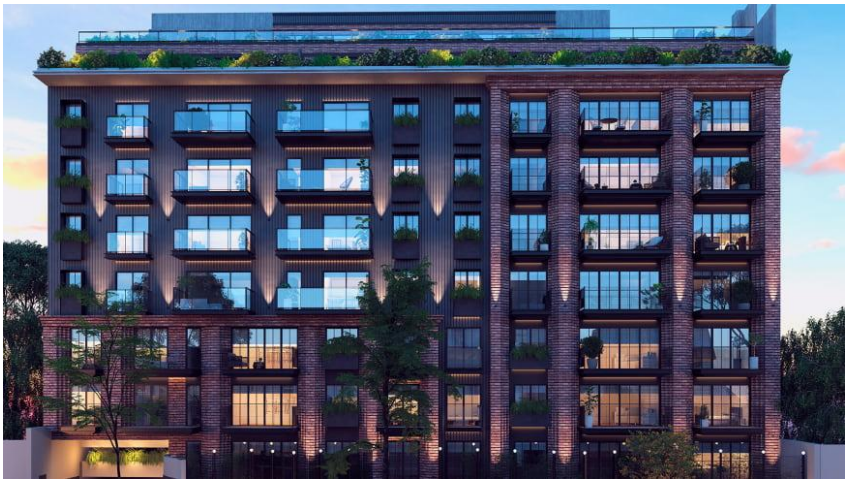


Image showing the façade for San Fernando (Conventional Building)

Source: (https://vyv.pe/)

4. Results and discussion

This analysis determined the relationship between electricity, solar power, and water saving techniques in conventional versus green buildings in Lima, Peru. A study from the Ministry of Housing, Construction and Sanitation showed the difference between green and conventional buildings in Lima, Peru, and had various tables of comparison between different renewable energy sources. Some recommendations from this overview of the study would be that it would eventually be promising if buildings would start to be retrofitted and equipped with the necessary sustainable energy to be self-sustainable and to not damage the environment. Sometimes, due to people that have lower budgets than others, would not be able to implement energy types such as solar panels to their homes because of the high maintenance it requires, but that is exactly an example of why water saving techniques are the best for economic homes. Water saving techniques do not require certain special maintenance for the implementation of different taps, or toilets for example.

4.1. Solar power vs. electrical energy

The table used contains the difference in cost between solar power andelectricity in renewable buildings vs. conventional buildings in a study carried over 15 years. With this data collected in table 1.1, a correlation betweenthe two variables was performed, to analyze the relation between the data, which the ‘r’ value turned out to be a perfect 1. It can deduce that this correlation between the two datais almost perfect, because it turned out to be a 1. Both values will rise throughout time, inthesame correlation pattern because of the country’s inflation and rise of values. On the other hand, the development two graphs were made, where the first one states the relationship of both variables throughout time in different sets of data, versus the

secondgraph that states that we can study the same data but comparing both variables in the same graph. In both cases, there could be a speculation about a certain trendline causing a positive correlation between the two.

4.2. Water Consumption vs. electrical energy

For the water consumption results, two tables were made, 1.2 showing the annual consumption of water per household, being those a conventional and sustainable household respectively. For table 1.3, the potential water savings were shown throughout different levels of the possible savings a building could sustain. Both of these tables are very important for the research of these water savings because in the construction world and especially in Peru, water is one of the main components of its high levels of consumption and one of the main reasons for global warming and climate change. Implementing these new ways of preventing the high levels of consumption for these conventional buildings could potentially make a difference in the consumption of water in buildings and constructions.

5. Conclusion

This study explored the different possibilities of developing a building, whether sustainable or conventional, and found the contrast in costs between both factors. The capstone is based in Lima, Peru, where most buildings are conventional, and the study was purposely made to raise awareness of the situation taking place regarding climate change in the world, especially in Peru, where this branch of sustainability is not yet explored. The study also sought to know whether solar power and water-saving is the best option to reduce yearly energy costs or if it

is a better option to keep it conventional.

The study's main findings were to compare the results from two similar buildings, one which was sustainable (ran on solar power and water-saving techniques) and one which was conventional. These two buildings were homes, and had the same terrain, apartment areas, and the same method of construction: the only notable difference between the two was the type of energy used. Also, the method of construction is a conventional construction system with reinforced concrete columns, plates, and beams, together with solid reinforced concrete slabs to achieve a load-bearing structure for seismic and gravity loads. Not to mention, they are both designed by the same group of architects and constructed by the same construction company (VYV) based in Lima Peru.

It was crucial to investigate an external model of costs that would help as an example of how sustainable energy works compared to electrical energy. A model is a basic comparison of solar energy costs versus electrical energy costs and is reliable to further inform the research. After comparing the costs for solar energy to electrical energy, the results were promising. The expected cost for 15 years on electrical energy was more than three times the cost for energy throughout solar panels, which supported the initial hypothesis.

After researching a base model in the implementations of these types of energy, there was further exploration for the specific purposes of the energy in buildings, specifically in housing. As mentioned beforehand, the study was on investigating two similar buildings that run on different kinds of energy. The second part of the investigation was to explore water

savings in the building.

As a general overview, for water-saving techniques in the comparison of the housing units, there was a 30% costly savings for when using these techniques that would consider the housing as sustainable. When digging into the detailed specifics about water-saving techniques, there are four levels of savings, as seen in Table 1.3. The results were also promising because in Peru, specifically in Lima, there is a dilemma when talking about water consumption since there has not been a majority of people implementing this type of sustainable method in their homes.

After the findings of this study, it can be said that the easiest and most feasible way to save money and help the environment is by water recycling in homes and buildings. Here, water goes through a cleaning cycle. The ‘grey water’ can be reused for gardening, drinking (potentially by filtration), cleaning (potentially by filtration), and cooking (potentially by filtration). Water is a finite resource that is under looked by societies, and it may be one of the main reasons why there is a very high contamination index in some countries.

Finally, after the whole investigation, we can answer the hypothesis: there would be a lower cost of investing in sustainable energy than conventional energy in the long term. There is a vast difference in costs if comparing these types of energy. Conventional energy is often applied to most buildings worldwide because it is easier than solar, and most people are unaware of potential alternatives. Having conventional energy in a house is far easier than developing trusting sustainable energy because of the technology it requires. In contrast, in

the long term run, the idea of initializing sustainable housing would be beneficial for those who would want potential future savings in costs of energy. As architects and designers, it is up to us to educate clients on the need for renewable energy upfront in a building's design.

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