The Environmental Effects of Smart Homes

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January 31, 2022

1 Introduction

Nowadays, more than ever before, people are becoming more and more aware about the effects their daily lifestyle is having on the environment. The subject of climate change and other threatening environmental issues is one of the most shared topics today.
Smart Homes are a new concept that has seen a lot of attention during the last few years. A smart home is a home where most appliances (TV, lighting, heating...) are connected through the internet. This allows users to monitor their appliances and control them whenever needed through their mobile phones.

Although this concept may seem to not have that much effect on the environment, the reality is contrary. A study conducted showed that smart homes can reduce energy consumption and CO2 emissions by 13% [1]. Not to mention the opportunity it offers for consumers to track their lives and completely control their home which largely increases their engagement in the environmental aspects throughout their everyday lives.

In this paper, we will be using data extracted from a real smart home [2], and studying the effect this smart home has on the environment through the daily behaviors of its occupants.

2 Expe-Smart House Project

This is a smart home project that is based on Open Source Hardware and Software. It was initiated in 2018 and it provides data from a 120 m^2 home that contains a family of 5 members.
This project offers access to around 340 measuring points in real time.

The available measures are as follows:

- Electricity, gas and water consumption of each device
- Temperature, humidity and brightness of each common room
- Opening position of each door and window
- Motion sensors
- Light state
- Air analysis of each room
- Outdoor weather conditions

Using the Grafana portal, we can view and extract any data needed. However, the data at this stage is still not suitable to be used.

3 Data Extraction

For the first step, the data needed for the study is identified. Each data has a code number that must be used and implemented into the Python code in order to transform this data into a .csv file. By obtaining the csv file, we can now see how the data is not clean: the time intervals on which the measurements are taken are not constant.

This of course affects the accuracy of the graph we would have if we tried to draw this data. Furthermore, we were more interested in visualizing the data hourly (some sensors have hourly data measurements but others measure every 5 minutes for example) because this simplifies the graph and allows better analysis and understanding of what's going on.

The data needed for this project are:

- Energy Consumption
- Power consumption of different appliances
- CO2 Concentration
- Luminosity

For the above stated reasons, an algorithm dedicated for data cleaning was required. The algorithm was implemented on Google Collab (using python language). The code used is the following:

```
#power
from re import M
import math
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt

df = pd.read_csv('Lumin.csv', delimiter=',')
time_data = df['Time'].tolist()
consumption_data = df['Salon'].tolist()

for i in range(0,len(time_data)):
  M=time_data[i].split(' ') #M[0] is date; M[1] is time
  Hour=M[1].split(':') #Hour[0] is the hour
  Day=M[0].split('-') #Day[2] is the day
  time_data[i]=Day[2]+Hour[0]

print(time_data)

clean_time_data =[]
clean_time_data.append(time_data[0])
clean_co2_data = []
clean_co2_data.append(consumption_data[0])
for i in range(0,len(time_data)-1):
  if (int(time_data[i+1])!=int(time_data[i])):
    clean_time_data.append(time_data[i+1])
    clean_co2_data.append(consumption_data[i+1])

fig, ax = plt.subplots()
ax.plot(clean_time_data , clean_co2_data, c='b', marker='o', ms=3, alpha=0.5)
plt.show()

df = pd.DataFrame(data={'time': clean_time_data, 'value': clean_co2_data})
print(df)

df.to_csv("CleanLumin.csv", index=False)
```

Figure 1: Code

Figure1 shows the difference between cleaned and uncleaned data for TV power consumption. The clean data X-axis values that are made to show the day and the time at once; the first two digits are dedicated for the day and the last 2 digits for the time. For example: 1422 is 14^{th} of January at 22:00. All days are in month of January only and for the year 2022.

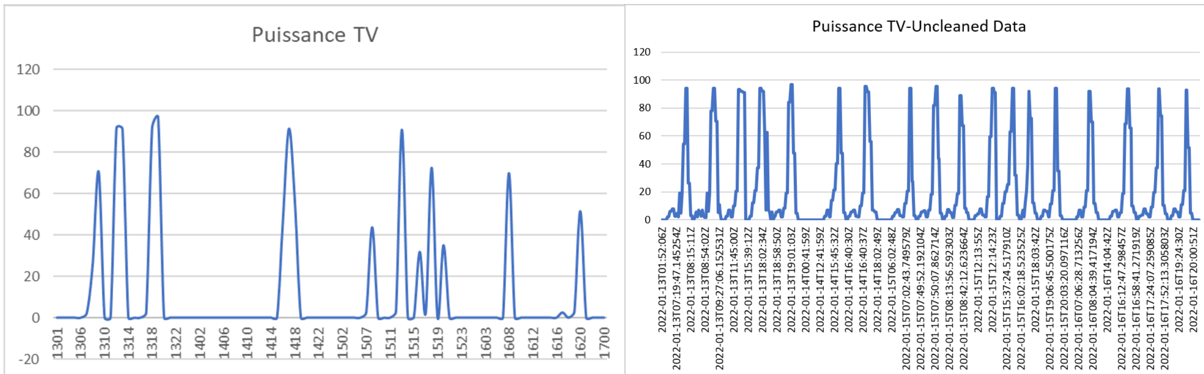

Figure 2: Clean Vs Unclean data

4 Data Representation and Analysis

In this part, we will be representing the data obtained in form of graphs and then performing their analysis. This will allow us to create a general idea of how families live in smart homes, how they consume electricity and energy, and if this smart home installation is really affecting their daily habits. All data will be collected for the period from 13/01/2022 till 17/01/2022 and with a time step of one hour.

4.1 Energy Consumption

If we take a look at the hourly energy consumption (Figure2), we can notice that it's variation is basically typical. The consumption is barely varying during the day, and shows peaks at 7:00 in the morning and 11:00 in the afternoon.

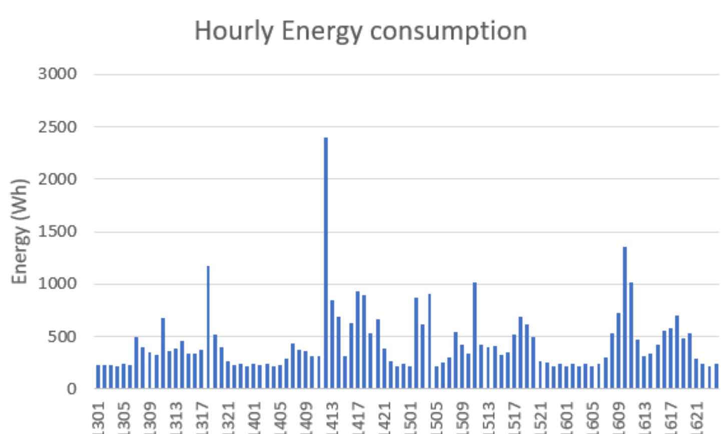

Figure 3: Hourly Energy Consumption

Basically, this is due to the fact that usually house members prepare themselves to leave home around that time of the day and this generates more energy consumption. In addition, they all return home at around 11:00 and perform their daily needs (cooking, turning on water heater, turn on the lights, TV...) which causes even higher energy consumption peaks than those that take place at 7:00.

One can also notice that for the 15 of January, the consumption is quite different and this is because this day happens to by Saturday, which is why the family members' routines differ and hence their energy consumption.

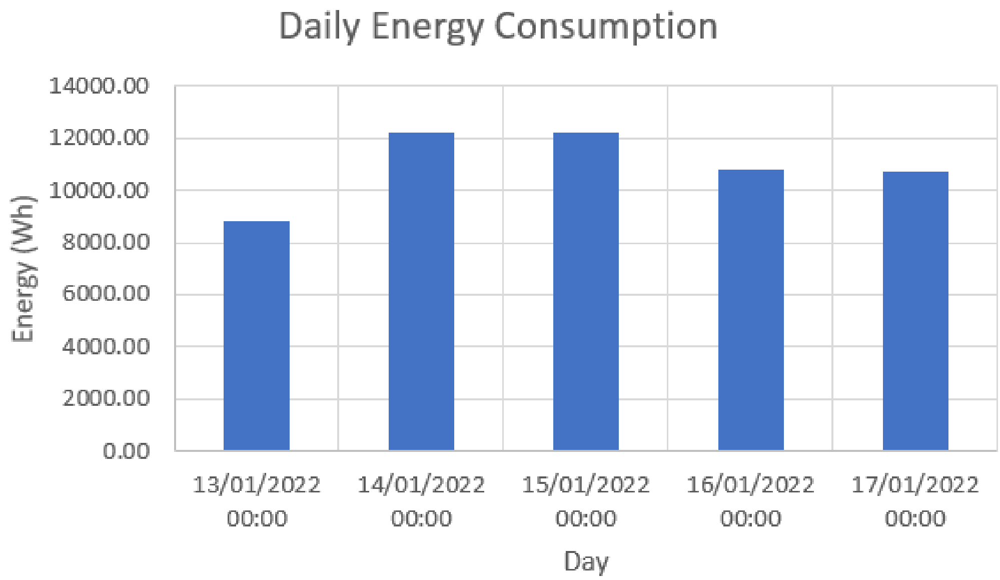

Figure 4: Daily Energy Consumption

The daily energy consumption of the family members has an average of 10KWh. If we take this average to calculate the average yearly energy consumption, we will get around 3800KWh. According to Engie, the average home in France has around 4700KWh energetic consumption each year [3]. Smart home devices such as LEDs, appliances, and smart plugs use less energy. In addition, most smart home appliances allow scheduling and remote control systems which plays a big role in energy-saving.

4.2 Power Consumption of Appliances

This section is dedicated to study the power consumed by different appliances installed in the house.

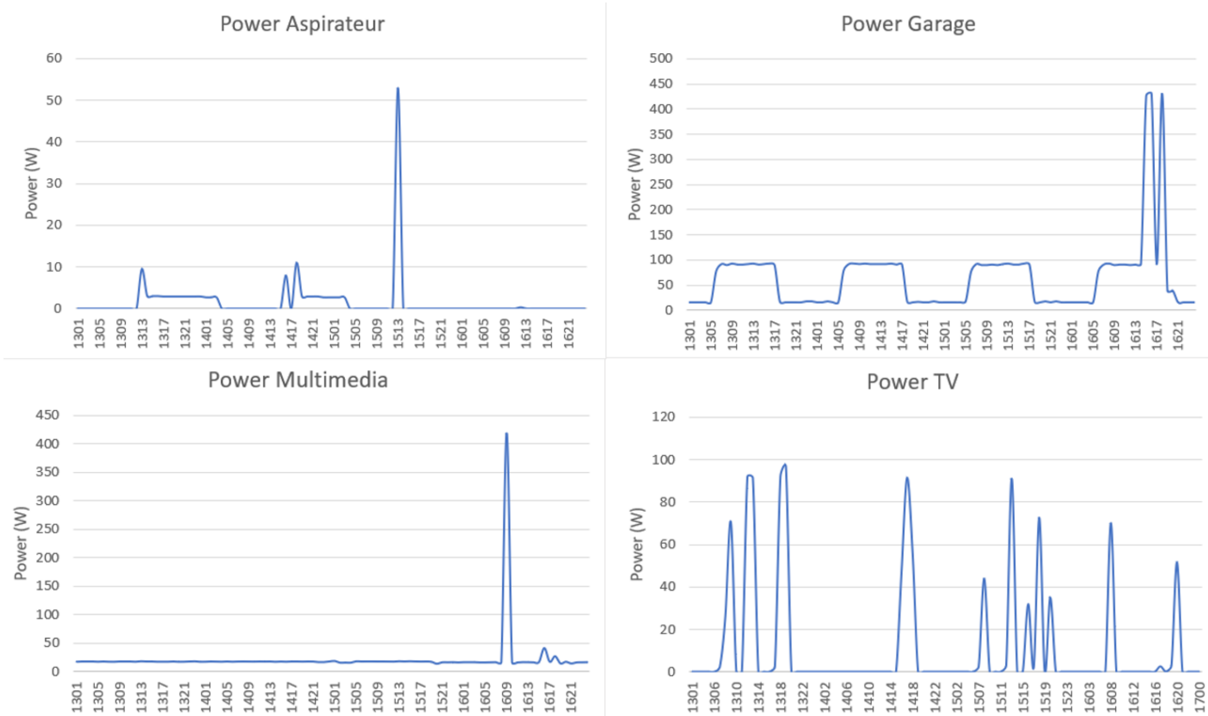

Figure 5: Appliances Power Consumption

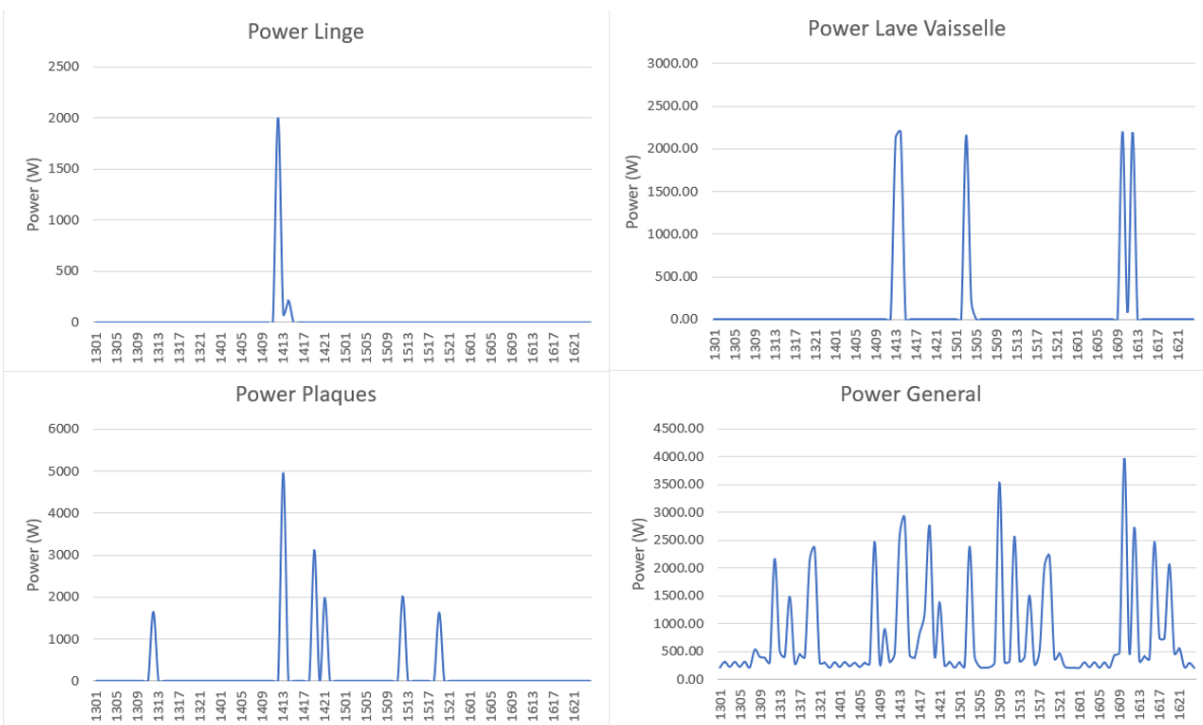

Figure 6: Appliances Power Consumption

The power consumed by most appliances is obviously intermittent. The trends show peaks at time of consumption, and then go back to zero. Although this is for sure possible in a non-smart home, it is basically much easier to attain in smart homes. This due to the fact that most smart devices automatically shut down when they detect that they are not in use. In addition, smart devices can be also scheduled to turn off at designated times. This reduces the duration of peaks in power consumption and hence increases the times where consumption is zero (devices are turned off).

The general power consumption is represented in the fourth graph in Figure5. We can notice that on a typical day, the families' power consumption is at it's lowest from 21:00 till the next day at around 5:00 or 6:00. These are the times where most members are not home. Except for the 15^{th} which is a Saturday, where the family consumed power for a longer time due to their presence at home all day. The peak can be seen on the 16^{th} of January (Sunday).

4.3 Luminosity

The luminosity can be detected in all rooms of the house, in this part only the salon will be considered as an example.

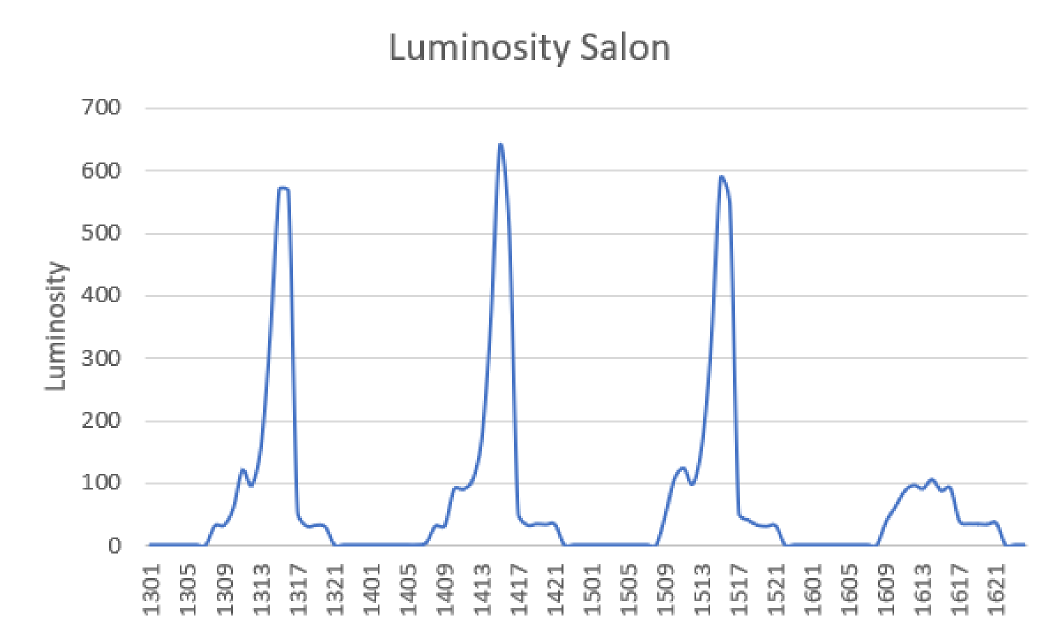

Figure 7: Luminosity in salon

We can note that the lights in the salon are almost always turned on in the middle of the day: from 3:00 till 17:00, after this time, they are reduced a little bit before being turned off at around 21:00. This shows the normal and predictable behavior of occupants. in addition to this, we can notice that on 16 of January which is Sunday, the lights were barely turned on, this is of course because on Sundays usually habitants leave their houses.

4.4 CO2 Concentration

A physical indicator can be used and enable us to estimate, with a precision, the occupancy in the house and more precisely inside each room. As it is scientifically proven, the presence of occupancy in a closed place may increase the CO2 concentration inside it. For this an identification and a representation of the CO2 concentration was done for each room.

Four hourly CO2 concentration charts were drawn for the 3 bedroom and living room during the study period.The results found are clearly detailed in the graphs below :

We can notice that all the graphs have the same shape, this reinforces our initial assumption that we have taken (the CO2 concentration is a great indicator to estimate the occupancy). In fact there is a simultaneous increase of the CO2 concentration in each room, this is due most probably to the presence of persons inside the house and this is proven regarding the shape of CO2 during nighttime (when people are sleeping, if we assume an normal behavior of residents).

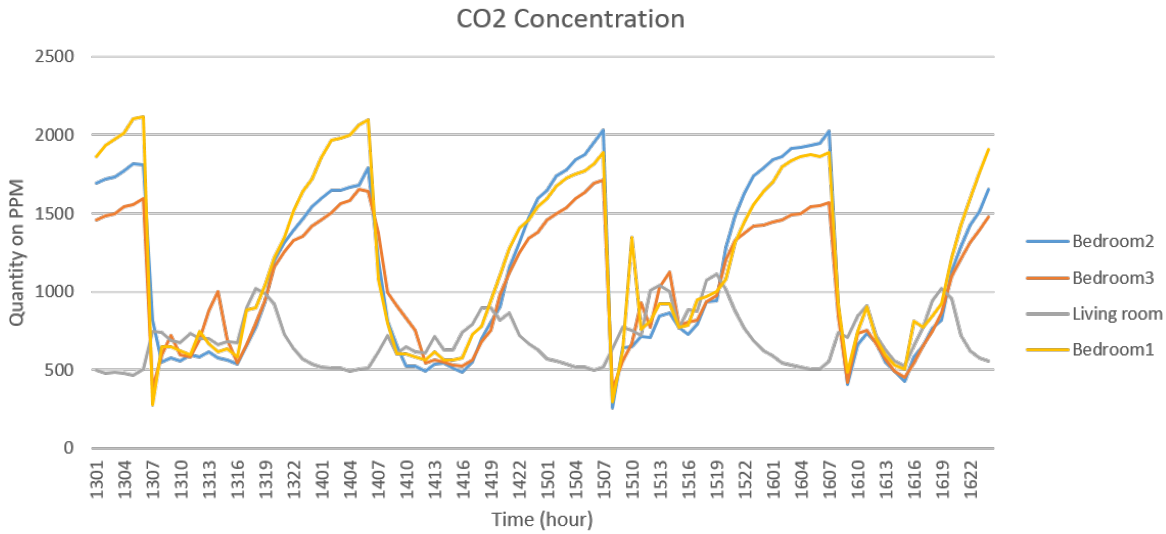

Figure 8: Bedrooms and Living room CO2 concentration

Spikes for each room and during the same period (for example for the period of time 13-12-2021 00:00:00 to 13-12-2021 6:00:00), As it is shown in each graph, were identified. We can notice, from these spikes, that sometimes the CO2 concentration inside bedroom2 as well as bedroom3 is above the limit comfort concentration (about 1500 PPM) [4]. Based on this analysis actions can be taken to reduce these concentrations (automatic ventilation for example).

4.5 Occupancy

Using the CO2 concentration, we can estimate the occupancy of a room. The code was implemented on Google Collab using python language. As explained in the previous section, the code will detect occupancy when the CO2 concentration increases.

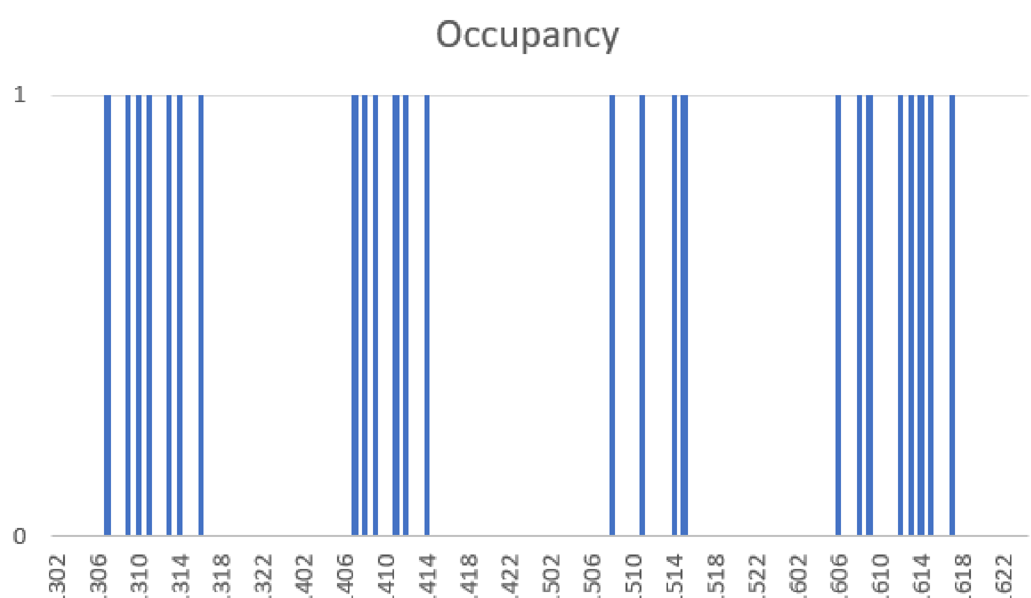

Figure 9: Occupancy in Room1

Room 1 was taken as an example. The occupancy detection plays a big role in regulating energy consumption. Using this feature, smart homes can dim or turn off the lights, turn off the heater, TV... when no occupancy is detected in the house.

In this case, one indicator (CO2 Concentration) was taken into account; however, occupancy detection can be done by taking into consideration other features such as power consumption, motion, lights state, acoustic pressure... This for sure offers more accurate results.

5 Conclusion

Smart homes are a great way for consumers to start engaging in reducing their energy consumption and acting for the environment. The ability to control smart devices from a distance or even when we are asleep through scheduling them to turn on/off when required to, gives the user the authority to control his consumption at any time. Not to mention that most smart and modern electric devices consume less energy to function because of their high efficiency.

Smart Homes play a big role in changing the mentality of consumers and pushing them to think about regulating their consumption; however, we cannot neglect the importance of the customers own mentality and engagement.

Consumers who are not aware of the environmental issues and their influence on the environment can use smart homes in an inadequate way that makes their disadvantages outweigh the advantages.

6 Webographie

[1] How Does Smart Home Automation Affect the Environment
https://www.envirotech-online.com/news/environmental-laboratory/7/breaking-news/how-does-smart-home-automation-affect-the-environment/45838#: :text=Previous%20studies%20on%20the%20subject, down%20CO2%20emissions%20by%2013%25.

[2] EXPE-SMARTHOUSE Project
http://expe-smarthouse.org/index.php/en/project/.

[3] Average Consumption of Electricity in France
https://particuliers.engie.fr/electricite/conseils-electricite/conseils-relever-compteur-electricite/consommation-electrique-francais.html

[4] Le Dioxyde de Carbone dans l'air Intérieur.
https://ccnse.ca/documents/practice-scenario/le-dioxyde-de-carbone-dans-lair-int%C3%A9rieur: : text=Une%20concentration%20de%20CO2,un%20risque%20pour%20la%20sant%C3%A9%20%C2%BB.