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The Impact of COVID-19 on Energy Usage in the U.S. (A nationwide case study)

Rasha Almshekhs, Rawan Karam, and Salahaldin Alshatshati
Department of Mechanical and Aerospace Engineering University of Dayton, Dayton, OH

Abstract— This report explores the effects of COVID-19 on household energy usage. Some of these effects are associated with the changes that happened after the COVID-19. The study also presents the different trends in the different households and what changed in the energy usage and if something is going wrong. The report will discuss the results and whether the energy usage decreased or increased or remained the same after COVID-19. The trials are from 35 households. It is collected from different cities in the United States and for different family sizes. The results of this study show the impacts of the COVID-19 in three different trends. The three different trends will be explained in detail and compared to before the pandemic.

Keywords—COVID-19,Pandemic, Lockdown, Energy consumption, Household energy, Cornovirus.

I. INTRODUCTION

At the end of the year 2019, a new virus was found that made a huge change in people's life and all over the world. This new virus was spreading between people quickly and moving from China, where it was first discovered, to another countries. Many countries did not take serious measures in the beginning to protect their people. After finding several cases in many countries and finding a rise in the number of cases affected by this virus, countries began to be more strict to contain the spread of the virus. Coronavirus affected many people and killed many others which resulted in closing shops and schools and keeping people from going out [21]. COVID-19 have influences on all the life sources from human, to economic, and health. The spread of Coronavirus affected the energy consumption and not only residential but also govermental and commercial energy consumption. Many researches and studies took place to highlight the effect of the COVID-19 on the different life aspects especially on health, economy, social, resilience, and energy. Also, many of reaserches are still in progress at different stages to study the effect of COVID-19 on all aspects of life. According to many studies, "Power consumption dropped 4% compared to the same time period last year" [1]. This is related to commerial and govermental buildings. With the spread of coronavirus, many people had to quarantine and spend much more time at home. People had to work and study at their houses in order to decrease the spread of the virus. Schools and companies had to take serious measures to control the situation. Moreover, the patteren of the energy usage has changed a lot after COVID-19 as many buildings like schools and companies became empty and residential houses and apartments became occupied. This paper discusses the differences of usage of electricity, water, and gas before the coronavirus and after to build an idea on the consumption changes through the pandemic. In this study, data was collected by students from 39 different cities and houses to look over the consumption of gas, water, and electricity. The general thought is that Coronavirus added to people's daily demands which resulted in an increase in the usage and the price paid for the energy bills. This investigation helps in understanding the impact of the coronavirus on households and quarantine impact on energy usage. Using the collected data, it was found that there are many trends of the energy usage in the different households. The individual behaviors played an important role in the trends of the energy usage whether it decreased, increased, or remained the same. Another than the indiviuals behavior, the location of the household also plays a role in energy usage changes as some houses are from a hot and dry climate like Texas and others from extremly cold weather regions. This difference in weather affects the usage especially cooling and heating systems that may be running by gas or electricity. All the results and the possible reasons will be described in the next sessions of this report.

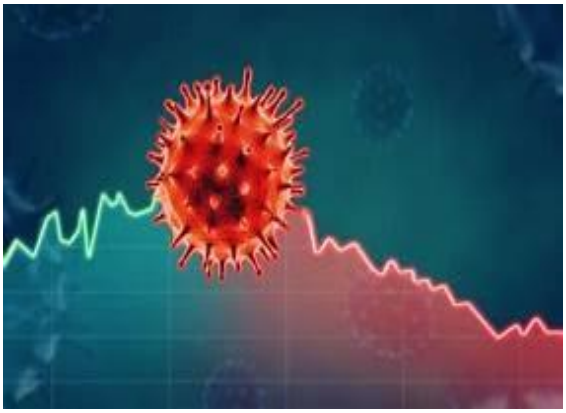


Figure 1: COVID-19 and energy usage

II. BACKGROUND

In this paper, the focus is to study the effect of the pandemic on the energy usage using data from different cities. According to statistics and projection data from the International Energy Agency (IEA), the global energy demand in 2020 is estimated to decline by 6% compared to 2019 [2]. This decline is due to the closure that happened all over the world. This report studies data from 2019 to 2020 in the United states of America collected from different states and cities. This report will help in understanding what happened when people moved from interacting with each other to communicating using electronic devices and staying away from each other at their own houses.

It shows what happened when students from different ages and schools moved from studying in the educational buildings and campuses to online studying from their houses and using laptops instead of pen and papers. Due to the spread of coronavirus, people were advised to take extreme hygiene measures to contain the spread of COVID-19 like wearing masks, washing hands and staying six feet away from others. Poor countries and countries which is in wars have energy access problems that affect their health care, and they are more likely to be affected by the virus as they cannot follow the instruction to contain the virus [9]. For example, India is one of these countries that have very poor citizens and shortage of medical supplies. India is sufferening and the virus is spreading among all the population. Moreover, it will study how the households patterens has changed and what is the affect of this change. Countries had lockdowns with the spread of the coronavirus which caused many places to close. Some countries forced partial curfews and some of them had full curfew.An article mentions that many countries had a decline in the overall electricity consumption during the pandemic of COVID-19 including Italy, Canada, Turkey, China, and Brazil [5]. This decline is because the shutting down of commerial places and big companies and buildings that was using huge amounts of electricity, water and gas. Many countries like Kuwait had a reduction in commercial and industrial consumption and enlargement in the residential sector [6]. This growth in residential building is due to the increase in occupancy and this increase is a main factor in the energy consumption changes [8]. Weekends are the time that students and workers relax, go out and do their favorite outdoor activities. Due the closure, people were restricted from going out and stayed spending their time at home. Comparing weekends before the pandemic to weekends after it, the energy consumption was lower on weekends after the pandemic due the closure of public places and people cancelling their gatherings [19].

III. GOALS

The main purpose of this report is to study the effect of the COVID-19 on household energy consumption. It will focus on water, electricity, and gas usage and compare between the usage in 2019 and 2020. This report focuses on the advantages and the disadvantages of the pandemic in the COVID time on the energy consumption. The goal of this study is to show and give a brief explanation about the individual behaviors after COVID. What happened when people stayed at home, what working from home has brought with it, and whether it helped to reduce the energy consumption or not. The results will show if the energy consumption changed and how did it change.

IV. CASE STUDIES

Data was collected by students at the University of Dayton from 39 different houses in different cities. The parameters of the study are the energy usage (electricity, gas, and water) in two years (2019 and 2020). Data will show the usage of electricity, gas and water staring from March 2019 till March 2021. Then, the data from these two years will be compared and illustrated in Excel graph to demonstrate if any changes happened. The house‘s owners differentiate in occupation, size, knowledge, and education. The collected data will draw as a chart by Excel sheet to verify the behavior of the energy usage and how it differentiate from the year before. Data was collected from different states and different cities. Different cities and states means different zones and different weather. Some cities have hot summer and mild winter, while others have mild summer and freezing winter. The occupancy changes in each households as well as the thermostat temperature. All these differences affect the energy consumption.

V. METHODOLOGY

The methodology package is designed to evaluate the impacts of the COVID-19 pandemic on the energy usage and consumption. Shortly, the report is focusing on studying the pandemic effect and how the energy consumption is affected by the changes that happended since the beginning of the pandemic. This study used the data collected from houses in different states in the United states. In general, all the data will be examined separately to see the difference between the different trends. A simple chart will be created between the data (electricity, gas, and water). The results will be evaluated to see the difference between the data for different houses. This helps to have a better understanding of the impact of COVID-19 on energy consumption. The results show three different trends as shown below:

a. Increasing in the energy usage
b. Decreasing in the energy usage.
c. Maintaining the energy usage.

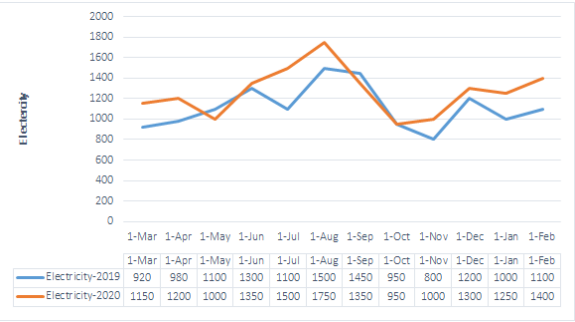
These trends are relying on the results that will be obtained from the study.

VI. RESULTS

The results of this study are presented across the combined data, based on the monthly collected data. First, the first trend of the collected data, a discussion of the effect of the COVID-19 on electricity, gas, and water. Before beginning, it should be illustrated that the individual's behaviors play particularly important roles on energy consumption. The results below will support what is illustrated.

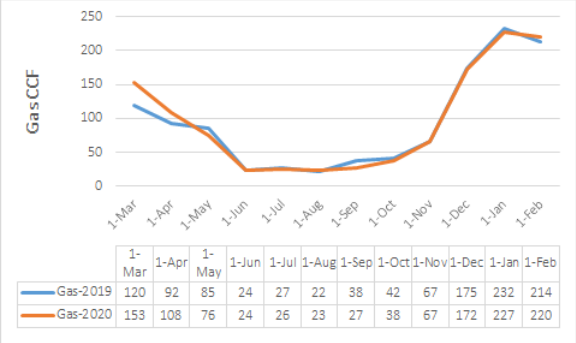
A. First Trend: Increasing in the energy usage:

The main implication here is that there is a big increase in the energy consumption after the COVID-19. The figures below show the electricity, gas, and water usage in a household in Avon/OH from March 2019 until March 2021:



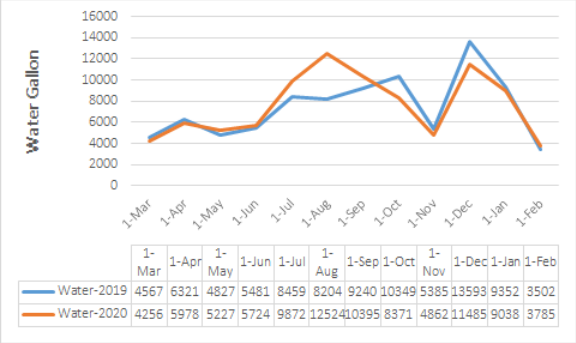
	1-Mar	1-Apr	1-May	1-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec	1-Jan	1-Feb
Electricity-2019	920	980	1100	1300	1100	1500	1450	950	800	1200	1000	1100
Electricity-2020	1150	1200	1000	1350	1500	1750	1350	950	1000	1300	1250	1400

Figure 2: The electricity usage for a house from 2019-2021



	1-Mar	1-Apr	1-May	1-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec	1-Jan	1-Feb
Gas-2019	120	92	85	24	27	22	38	42	67	175	232	214
Gas-2020	153	108	76	24	26	23	27	38	67	172	227	220

Figure 3: The gas usage for a house from 2019-2021



	1-Mar	1-Apr	1-May	1-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec	1-Jan	1-Feb
Water-2019	4567	6321	4827	5481	8459	8204	9240	10349	5385	13593	9352	3502
Water-2020	4256	5978	5227	5724	9872	12524	10395	8371	4862	11485	9038	3785

Figure 4: The water usage for a house from 2019-2021

As known, the electricity usage increases in June, July, and August due to the hot weather in these months and the increasing demands on the cooling system and the increase in these hot months is considered normal. Before COVID-19, as shown in figure (2), the electricity usage in 2019 was lower than in the COVID time. That could happen for many reasons:

a. A lot of people stayed at home and worked from home which helped in increasing the electricity usage because people used laptops, chargers, lights, televisions, air conditioning, etc.

b. People spent almost all their time in their houses. Since parks were closed and there are not any outside activities, people tried to find indoor activities that resulted in increase in the usage. A New York survey showed that electricity usage starts from the morning and remains the same till the time people sleep [8]. Many people spent their time using video games and televisions from the time they wake up till bed time because of boredom.

c. Online schools also contribute to a high percentage of increasing the energy usage. As all students moved from the traditional way of teaching to online environment that requires using smart phones and computers.

d. Most of flights were cancelled and some countries closed their borders. Some other countries had really difficult conditions to allow people to enter. Hence, people were unable to travel and have vacations like they used to every summer and they stayed at home.

e. Since outdoor activities and pools were closed, many families got water slides, pools, and bouncy houses for their children that added to the water and electricity usage.

f. Many college students went back home in a time they used to be at college dorms to quarantine which added to the number of individuals in the house.

g. More gas usage due to cooking food at home and not getting food from outside. As many resturants closed during the pandemic.

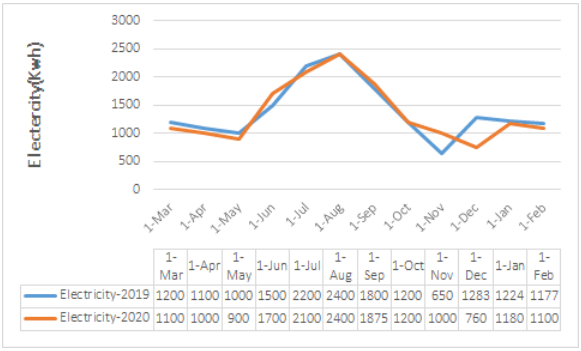
h. More hygiene measures were taken which resulted in increasing the water usage. People were asked to wash their hands frequently. Some poor countries have limited access to water and some families barely find water to drink. This growth in water consumption increases water problems around the world in poor countries [4].

For the gas usage, as shown in figure (3), the gas usage before and after the COVID-19 are close to each other. There is no big difference in the amount of the gas usage in the household. Both gas lines have the same trends in 2019 and 2020. The gas usage increases in December, January, and February due to the cold weather and heating needs where some houses heating systems works by gas. People used to turn on their heating system at night or in the cold hours. This behavior stayed the same after COVID-19, so there was not a big difference in the gas usage. Heating and cooling needs were the same before and after the pandemic which kept the usage constant.

For the water, there are some increases in June, July, and August because of the hot weather in these months. More shower time is taken in the hot weather while locked at home and having outside pools closed. As mentioned before, some activities at home like water slides and swimminh pools consumes huge amount of water which causes an increase in the usage.

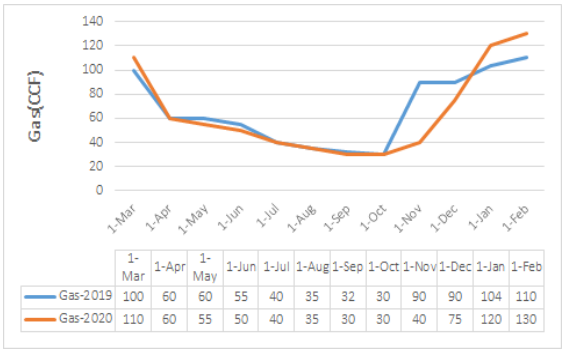
B. Second Trend: Maintain the same trend before and after COVID-19:

The main idea in the second trend is energy consumption remained the same after coronavirus. The figures below represents the consumption for electricity, gas, and water for a house in Cincinnati, Ohio.



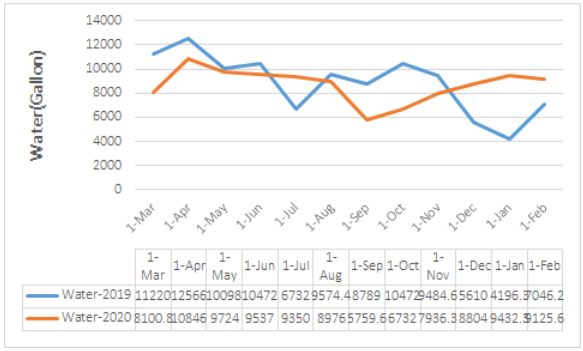
	1-Mar	1-Apr	1-May	1-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec	1-Jan	1-Feb
Electricity-2019	1200	1100	1000	1500	2200	2400	1800	1200	650	1283	1224	1177
Electricity-2020	1100	1000	900	1700	2100	2400	1875	1200	1000	760	1180	1100

Figure 5: The electricity usage for a house from 2019-2021



	1-Mar	1-Apr	1-May	1-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec	1-Jan	1-Feb
Gas-2019	100	60	60	55	40	35	32	30	90	90	104	110
Gas-2020	110	60	55	50	40	35	30	30	40	75	120	130

Figure 6: The gas usage for a house in 2019-2021



	1-Mar	1-Apr	1-May	1-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec	1-Jan	1-Feb
Water-2019	11220	12566	10098	10472	6732	9574.4	8789	10472	9484.6	5610	4196.3	7046.2
Water-2020	8100.8	10846	9724	9537	9350	8976	5759.6	6732	7936.3	8804	9432.3	9125.6

Figure 7: The water usage for a house from 2019-2021

In figure (5), it is noticeably clear that there is no big difference in the electricity usage. As it is said previously, this study is highly affected by the individual behaviors. Both electricity lines for 2019 and 2020 have the same trends and amount. That could be for:

a. The awareness of people increased after COVID-19. People knowledge is increasing day by day in this world especially with smart phones and social media. Many people nowadays care about using renewable energy and saving more energy to protect the world they live in.

b. Saving money. A lot of people lost their jobs. Unployments rates were expedited to reach 32% in the second quarter of 2020 [7]. As a result, they tried to cut some of the bills. That helped in maintaining the electricity usage even though they are at home all the time.

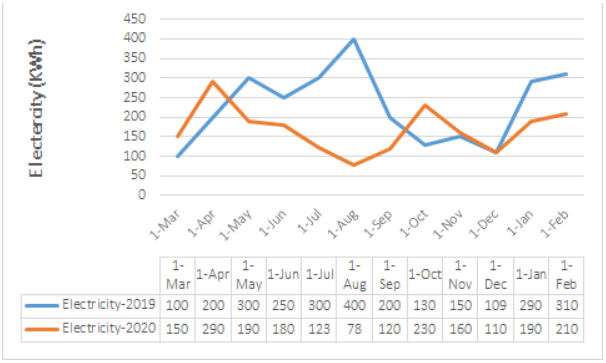
c. The awareness of the people was extremely low before the pandemic that they did not care to close any unused appliances and lights to save energy.

Figure (6) for the gas usage shows the same results as the electricity and that could be for the same above reasons.

The decreasing in the water usage shown clearly in figure (7). There is not a clear reason why the water usage fell at some time. A reason could be that the house owners may had a leakage and did not know for all that time or maybe the owners were away for these months.

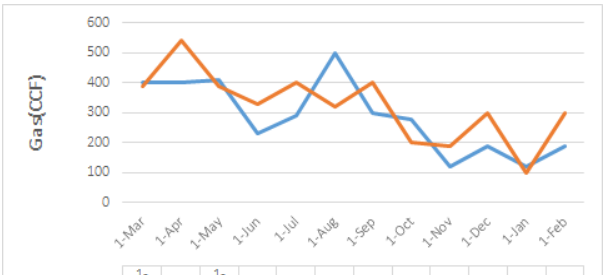
C. *Third Trend: Decreasing in the energy usage:*

The following figures of electricity, water and gas usage are for a house in Cincinnati, OH where five people live there, and the thermostat temperature is set for 68 F.



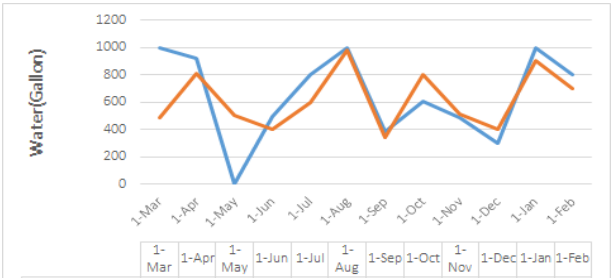
	1-Mar	1-Apr	1-May	1-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec	1-Jan	1-Feb
Electricity-2019	100	200	300	250	300	400	200	130	150	109	290	310
Electricity-2020	150	290	190	180	123	78	120	230	160	110	190	210

Figure 8: The electricity usage for a house from 2019-2021



	1-Mar	1-Apr	1-May	1-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec	1-Jan	1-Feb
Gas-2019	400	403	410	230	290	500	300	280	120	190	120	190
Gas-2020	390	540	390	330	400	320	400	200	190	300	100	300

Figure 9: The gas usage for a house from 2019-2021



	1-Mar	1-Apr	1-May	1-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec	1-Jan	1-Feb
Water-2019	1000	920	0	499	800	1000	390	609	490	300	1000	800
Water-2020	490	807	509	399	600	980	340	800	510	403	908	700

Figure 10: The water usage for a house from 2019-2021

As shown in the above figures and especially in figure (8), the usage of electricity has dropped in year 2020. This could be for these causes:

a. Some of these household workers are first liners and work in medical institutions that they had to work all the time in the pandemic.

b. Many members lost their work or got lower salaries during the pandemic that people really cared about saving energy and lowering their bills.

c. People may have moved in the pandemic to the elderly family members house to assure

that they are healthy and having all their essential needing's. Also, some people prefer to stay with each during the pandemic to stay positive and feel safe.

d. Some families may have installed a solar or geothermal system that results in decreasing the electricity usage.

In a case study in Plano, Texas, the usage of water was lower during the lockdown than before COVID-19. Asking one of the house members, he mentions that they had a water leakage, and they were travelling so they could not fix it since they were away which caused the usage to be so high. Also, in June 2020, during the pandemic, the family members travelled which made the usage lower. Another case in Miamisburg, Ohio, the family left for a vacation in December and January 2021 which caused a decrease in the usage for both water and electricity.

D. The overall impacts of COVID-19 on the energy usage

Relying on the given data and the correlation that is made, the following figures below showed the results to verify the general behavior of the energy usage. Moreover, the differences between 2019 and 2020 will be clear. The bar charts below of the average usage for each month in the years 2019 and 2020 for energy usage (electricity, gas, and water). Figure (11) shows the average monthly electricity usage in 2019 and 2020. There are two main areas. First, there is a big increase in the electricity demand in ten months. The second area is in October and November. The electricity amounts are approximately the same in these months. The close average in October and November could be because business started to open back and some students went back to campuses and schools.

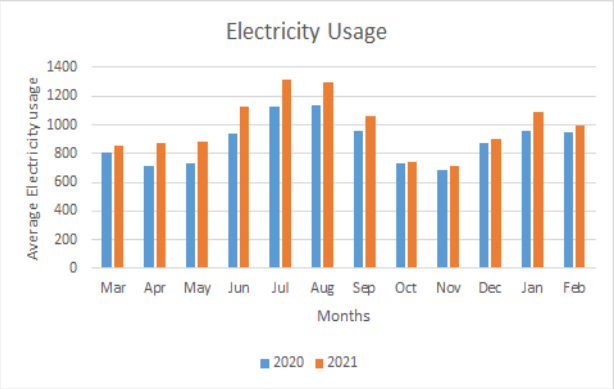


Figure 11: The average electricity usage for 2019 and 2020

The average monthly gas usage in 2019 and 2020 shown in the below figure. There are some increasing and decreasing areas. In the cold months (January, February, March, and April), there is a big increase in gas usage. This could be for the increase of the heating demands in winter. Also, in May and June, the start of the summer, the cooling needs and the increase of the occupancy after the pandemic caused the gas usage to be higher.

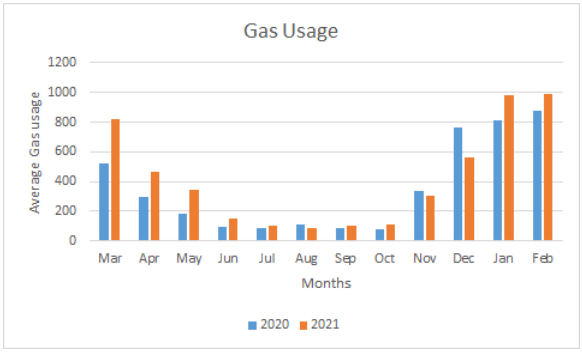


Figure 12: The average gas usage for 2019 and 2020

The average water usage remained approximately the same for both years. The stability of the average water usage is due to the same reasons mentioned before.

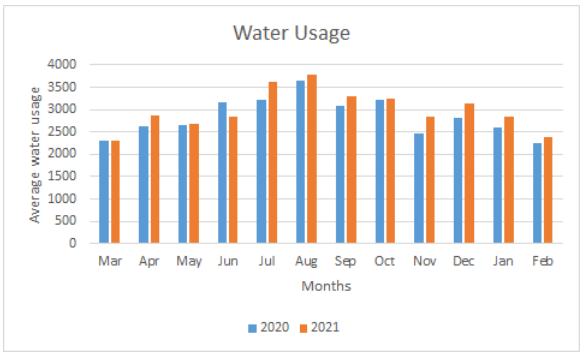


Figure 13: The average water usage for 2019 and 2020

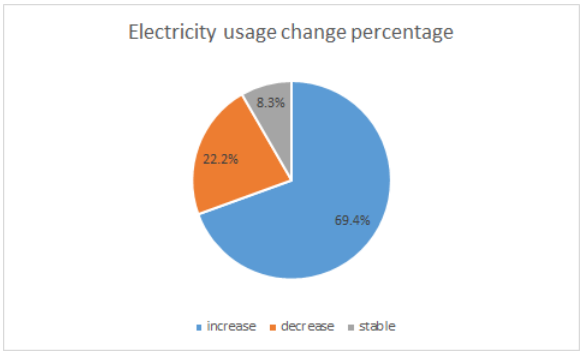


Figure 14: The percentage of change in electricity usage

As illustrated in figure (14), most of the households had an increase in the electricity usage with a percentage of 69.4%. This pie chart consists of 36 data sets with three stable data, eight data that showed a drop, and twenty-five data with increase in electricity usage. The reason why only 36 data were taken out of 39, is that the other three data were missing values and cannot be included. According to the "COVID-19 and household energy implication: what are the main impacts on energy use?", it mentions that the total household energy usage increased as the activities inside the households that use electricity increased. As said before, many people had to stay at

their houses and the occupancy increased. There was an increase of 40% in cooking and lighting, and 60% in heating and cooling [2]. This is due to resturants closure and staying at home all the time with lights on. These activities which had a rise during and after the pandemic affected the electricity consumption and caused a growth. This increase in electricity consumption would result in an increase in energy bills which would cause insecurity for low-income households [7]. Low-income families used to struggle paying their energy bills since before the pandemic. These families that used to have problems paying the bills since before the pandemic would face bigger problems even after the pandemic.

VII. Conclusions and discussion

The data that was collected could not be accurate and complete. Some of the data was missing one or more values from the energy usages. Having a missing value results in inaccurate data and loose outcomes. A case in Kansas City, Missouri, the only usage that was provided is the electricity usage therefore, this household could not be compared to others in other usages like water and gas. Another case in Evansville, Illinois, the only data provided was for electricity usage from March 2020 till February 2021. Having only one year data would not help in the study as it cannot be compared to the previous year before the pandemic and the look at the effect of COVID-19 on the electricity usage. As mentioned before a case in Plano, Texas, the house had a water leakage which does not give a good understanding of the water usage. A case in Dayton, Ohio, gave the water usage for every three months combined while in other cases, the water usage was provided for each month separately which makes it hard to compare it to other cases. Another case in Beavercreek, Ohio, has installed a geothermal HVAC system and there is no gas used in the household. The geothermal HVAC system surely affected the usage but it would be insufficient to compare it to a year that did not include the geothermal system. Another reason is that some households do not keep a constant thermostat temperature as in the Rome, Georgia case where the thermostat is usually between 65 and 72. Changing the thermostat regularly affects the energy consumption every time. Also, in this case, the number of individuals changed during the data collection period. A similar case in Troy, Ohio, where the number of people kept changing throughout the year. It is clear that if an increase in occupancy happens, an increase in the usage would happen too and vice versa. To have a better observation and understanding, it would be better to have households that use all three energy sources to keep track of all of them. These results cannot be reliable for energy consumption to be compared with other old data because this data was taken under different circumstances [15]. These results were taken under certain circumstances and different from any other time before. The closure and curfews that happened during the pandemic have not occurred a lot or any time soon before.

Many families have suffered from the coronavirus that made a big difference in their daily routine and changed so many things around them. One of the things that has changed is the energy consumption. The analysis shows that the trends were different in each household. Some households had a sharp increase due to an increase in the activites that uses water, electricty, and gas. Others show a decrease in energy usage, and some of them remained stable. The increase trend had the bigger amount of households. The electricity consumption increased due to students attending schools online and members working from home and using many electronic devices that need a lot of charging. The water consumption increased to increasing in occupancy and using more water at home for cooking and bathing. For the gas consumption, the needs of cooling and heating increased and as families had to stay at home all day, their systems that uses gas were on for twenty-four hours every day. Since the increase in COVID-19 cases mostly was in summer and countries had lockdowns, a growth in family members has occurred in some households which resulted in more coolers and fans. When comparing pre-COVID period to the lockdown, most of the houses had much higher consumption rates in the lockdown period. This is because people had to spend their time at home and the increase in appliances use. People's life has changed completely from before the pandemic till now. If the situation continues to be like that many people should consider installing renewable energy sources at their homes that would really help lower their bills and produce more energy for the surge in energy consumption. Governments should raise the awareness of saving energy as some people used to waste a lot before the pandemic. Moreover, there is a lot of decrease in the energy demand after COVID-19. That happens because of the lockdown when a lot of big companies shut down and their big buildings closed. As mentioned before, many families could not travel. Closing the borders of many countries and cancelling flights to contain the spread of COVID-19 are some of the reasons for decreasing CO2 levels [10]. This is considered as an advantage of the pandemic as it helped the environment and lowered the usage of fuel. Comparing the increase in the household's energy usage with the decrease that happened after lockdown, the COVID-19 had a huge advantage on dropping the energy usage overall.

VIII. Limitation of the study

As this is new and ongoing situation, these results need updates in each stage. New variables should inculded and it could expanded in many different countries and cities. Many data and samples will help to improve the study and make the results more accurate. Later study with more data in differnent states and different households will highlight the impacts of the COVID-19 in a clear picture. Hourly data will help to study the individual behaviors affect on the energy usage. A detailed model with many different important variables that is able to change according to updated data will assist to establish a perfect model to study the affect of the unexpected events such as COVID-19. This study was only done in the United States of America and the data was collected by students and may be incorrect. Having data from all over the world would give a better perspective on the changes that happened. Also, this data should be compared to other data that was taken in a crisis time because they were taken in an expectational timing.

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