HiMCM: Problem A

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Summary

With the spread of transportation and communication technology, the world is more interconnected than ever. Public spaces are continually expanding their availability of electrical outlets. However, improvements and accessibility comes an unprecedented rise in electricity consumption and costs. It becomes necessary to consider the impact of increasing “free” charging stations and determine where to distribute the costs.

Electrical, demographic, and probabilistic statistics were researched to compute the increasing prices of energy consumption. Data from the U.S. Energy Information Administration (EIA) and the Global Energy Statistical Yearbook 2019 demonstrated that while total net energy generation is plateauing, there is an increase in the use of phones and electric vehicles. Data collected between 1990 to 2019 by the EIA demonstrated that the price per kWh is increasing and nearly doubled since 1990.

Buildings and public spaces will be designed and remodeled to fit the growing charging needs of phone and electric vehicle users. These impacts and requirements were considered for the algorithm, programmed using Java, to model the increasing fees of energy usage in public places. The number of smartphones, laptops, and electric cars charged per day were computed with the average time spent in each location, number of people, the percentage of ownership per device and average number of devices charged. The unit price for each kWh was then multiplied to determine the cost spent on electricity per day. For each device, the final number was then multiplied by 365.25 days for the annual fees on the product. The net annual energy fees were every annual device costs added together. For predictions, increase in population and potential changes in the daily amount of people and average time spent in the environment did not change. By inputting data from 2019 to 2030 (airport), the increase in energy fees should be $31612.39, which is 197 % increase from the $10617.82 from 2019.

This drastic increase suggests multiple possibilities for maximizing energy uses while minimizing cost. One of them is to turn on power saving mode, which hypothetically reduces the power consumption of each device and causes a significant net decrease in the amount of daily energy usage. Another possible solution is to instill an artificial limit at each charging station, which effectively decreases the average charging time. A third method is to encourage users to monitor their charged devices closely, ensuring that fully charged devices are plugged. This preserves user freedom while leaving a positive impact. Renewable energy also produces a net decrease in production costs and the added benefit of less carbon emission.

By finding alternative sources for energy or instilling stricter regulations, the price of electricity will significantly decrease while maximizing energy expenditures for everyone.

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Problem Interpretation:

Problem A has 4 main components to determine the financial impact of charging personal devices at public charging sites:

1. Analyze the change in energy consumption in recent years and project future expenditures; identify the impacts on, and requirements of public places with increasing electrical demands.
2. Develop a model for the resulting costs of increased demands of energy usage in public places, and discuss the extent and distribution of costs.
3. Discuss how the model changes for different types of public places.
4. Give suggestions on how to adapt and minimize the increasing fees of energy usage, and how these modifications adjust the cost model.

The problem also entails presenting the findings and potential solutions in the format of a school newspaper.

Introduction:

Energy consumption is growing rapidly as smartphones, laptops, and smart cars keep people connected, informed, and sustainable. The recent influx in energy usage results in a growing increase of “free” public charging stations, with enigmatic consequences and resulting costs society must be prepared to intake.

For the model, statistics of three locations (a school, an office, and an airport) and three devices (smartphones, laptops, and electric cars) were chosen to offer a clearer picture of the energy expended everywhere in three key settings and for electronics with different sizes and diverse energy outputs.

In the following report, datasets of previous energy output trends were analysed to project energy usages in coming years and identify the overall impacts and criteria of increasing energy demands.

Next, settings and devices with the highest energy expenditure were identified, and statistics that account for the consumer behavior, energy outputs at charging stations, and energy costs were computed. Afterwards, a generalized algorithm was developed to compute the final annual price. After plugging projected data and trends into our algorithm suggestions to minimize the costs for increasing energy usage.

Lastly, the feasibility of the model was analyzed and proposal on how to reduce the costs of increasing energy expenditures.

Trends and Predictions:

Devices are charged using electrical energy. Figure 1 shows the total net electricity generation per year in a graph based upon data provided by the US Energy Information Association[21]. The graph shows that the total electricity sales increased in an approximately linear fashion between 1950 and 2008, then started to plateau between 2008 and 2019 in another linear function. Only data from the last ten years was used to predict the next ten years because the world is changing drastically, and a linear model will be most consistent with more recent trends, especially because it showed a significant difference. Using the equation generated using the data between 2010 and 2019, the anticipated electricity net generation in 2030 will be 4092 billion kWh.

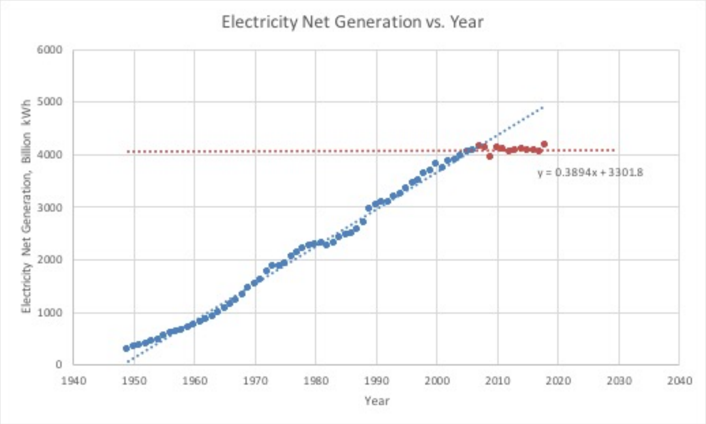

Figure 1. Data of the electricity generated from the years of 1940 to 2020 with a corresponding trend line with each portion of the graph. Data was taken from the EIA.

Over recent years, the usage of total mobile devices has increased, leading to an increased demand on public spaces for outlets and charging. The percentage of people owning smartphones increased rapidly in the first years of data collection, after smart phones were introduced to the market, as shown in Figure 2 [20]. The trend did not continue and will not continue at that rate because that would put the percentage of smartphone users over 100% in the next few years. To compensate for this, and make the model more accurate, the group decided to only analyze the last three years because the spike in smartphone ownership should be decreasing. This trend still put the percentage of owners over 100, therefore the percentage of owners can be approximated to 100%.

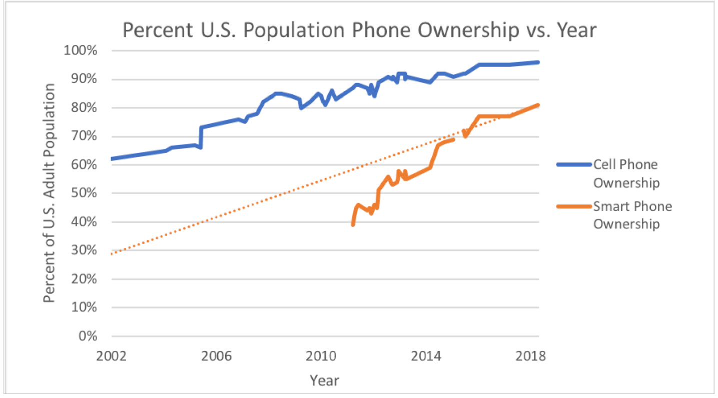

Figure 3. Graph of the smartphone and cell phone ownership percentage from the years of 2002 to 2018.

Similar research has been completed regarding the ownership of laptops. However, the overall trend was less clear and did not have a strong correlation as shown in Figure 3 [20]. Therefore, the ownership of laptops is going to be kept constant at 74%.

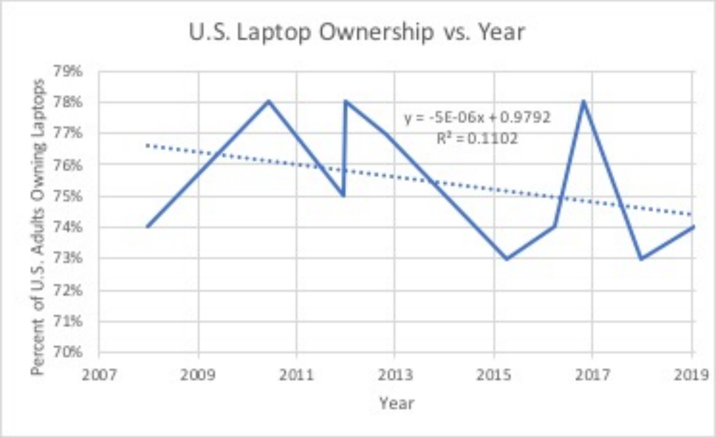

Figure 4. Percentage of laptop ownership between the years of 2007 and 2019.

The power it takes to charge an electric vehicle is greater than the power to charge either a phone or a laptop. There were 1 million electric vehicles currently in the US in 2018 but projected to reach 18.7 million by 2030 [19]. The percentage of people with electric vehicles is found by dividing the number of electric cars on the road by the population in 2030. Based on the U.S. Census Bureau's projections, the population in 2030 will be 355.1 million people, which means that 5.38% of the population will own electric vehicles.

As the amount of energy being sold increases, so does the price for one kWh. The cost of the energy of one kilowatt hour (kWh) has almost doubled over recent years. The cost of a kWh has increased from 6.46¢ in 1990 to 11.33¢ in 2019. The overall increase in energy impacts the public spaces more when the cost of the kWh is increased because they have to pay more. Based on the trend for the last 10 years, the projected cost per kWh is 12.897¢.

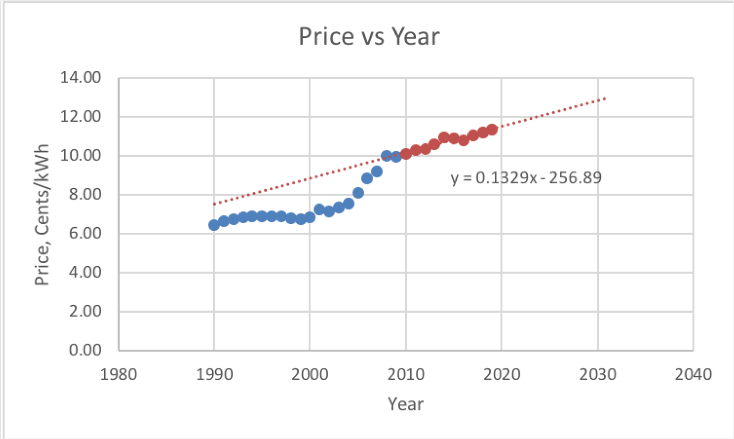

Figure 5. Graph of the price of electricity from the years of 1990 and 2020. A trend line was taken from the data points from 2010 to 2020.

The overall impact of these increasing values will increase the amount public spaces pay for their electricity, as will be shown in the model. The other impact on the space is what the space needs to keep consumers and visitors happy. Based on the trends, especially the rising number of electric vehicles and phones, public spaces will need more outlets and charging stations. The phone outlets need to be kept accessible, which may cause some spaces to remodel for practicality. For electric vehicle charging stations, public spaces will have to increase the number that they have for a demand that will be 18 times as much.

Model:

Intent of Model:

The model was designed to simulate the cost of the power demand for 3 main environments, and 3 main devices. The model uses the cost of kWh and the power consumption for 3 different types of devices over a day to calculate the annual power consumption and costs of outlet electricity for 3 different environments. The three environments are Industrial (ex. airports, train stations), Professional (ex. schools, office buildings), and Casual (ex. cafes, libraries). The 3 main devices considered were smartphones, laptops, and electric cars. Smartphones were chosen for their immense commonality despite their low power consumption. Laptops were chosen for their medium commonality and medium power consumption. Electric cars were chosen for their large power consumption despite their low commonality. Other devices, such as e-readers or tablets, are rarely brought out of domestic settings and have similar energy expenditures to phones. Though they can be added to the model, such devices are less impactful on the overall charging fees and for the purpose of simplicity were negligible.

Model Overview:

The model computes the annual electrical fees per day for a single environment, based on institution type and size. Overall, it flows through three key values: the number of devices being charged, the amount of energy used to charge the devices, and the price of a kilowatt*hour. This requires several iterations.

Values were derived for three specific places: a cafe (small and casual), school (average and professional) and airport (large and industrial), as well as for three devices: the phone (**P**), laptop (**L**), and electric car (**C**).

Percentages, consumers, and power consumption were all based on datasets from the United States. Computations are done for each environment.

The model uses demographics to find the number of devices that are charged in a building every day. Demographic averages were used for the number of people to pass through the building each day(**N**). Annual statistics, such as the yearly number of airport passengers, were then divided by 365.25 days to obtain the average daily visitors.

The number of consumers per day was then multiplied by the percentage of the population that owns any certain type of device (**DP, DL, DC**). The output is the number of devices in the building in one day. This value was then multiplied by the estimated probability of the device being charged publicly (**TP**, **TL**, **TC**).

The total number of phones (**QP**), laptops (**QL**), or electric cars (**QC**) daily is:

QP = N*DP*TP **QL** = N*DL*TL **QC** = N*DC*TC

The next value is the energy consumed by each device in a day, which was the product of the quantity of the device in the building, the average kW/h for the device (**WP**, **WL**, **WC**), and the average time spent in the environment (**H**). Power consumption and times that were initially presented as a range were averaged to standardize for different brands and variations in brand behavior.

QP*WP*H = **EPP** QL*WL*H = **ELP** QC*WC*H = **ECP**

For each device, the total energy charged was multiplied by the average daily energy costs for the device (**P**). Although it costs $0.13 for overall power, the EIA database from 1990 to present day indicates that the sales revenue for commercial power is $0.11.

P*EPP = **EPC** P*ELP = **ELC** P*EPC = **ECC**

As an equation that uses the predefined variables, the final annual energy fees (365.25***ETP**)for “free” public stations in any given year is:

365.25 * (EPP + ELP + ECP) = **ETP** (annual)

The total energy expended in the public place across all devices (**ETC**) is the summation of energy costs for each device:

365.25 * (EPC+ ELC + ECC) = **ETC** (annual)

All energy consumption and cost values (per device and total, daily and annual) can be calculated using a Java program made to generate the model (in Appendix)

The projected increase in energy is the **difference between energy expended in 2030 and the energy expended in 2019.** The increase as a percentage is:

In[∘]:= $\frac{\text{energy in 2030} - \text{energy in 2019}}{\text{energy in 2019}} * 100.00;$

Variable List:

- **N:** Total **N**umber of people per day in the environment
  - **NA: N**umber in **A**irport
  - **NS: N**umber in **S**chool
  - **NC: N**umber in **C**afe
- **H:** Average time (**H**ours) spent in the environment (charging time)
  - **HA:** Average **H**ours spent at an **A**irport
  - **HS:** Average **H**ours spent at a **S**chools
  - **HC:** Average **H**ours spent at a **C**afe
- **P: P**rice per kW*H
- **QP: Q**uantity of **P**hones charging per day
- **QL: Q**uantity of **L**aptops charging per day
- **QC: Q**uantity of **C**ars charging per day
- **WP:** k**W**/h average for a **P**hone
- **WL:** k**W**/h average for a **L**aptop
- **WC:** k**W**/h average for an electric **C**ar
- **DP:** Percentage of population with a **D**evice (**P**hone)
- **DL:** Percentage of population with a **D**evice (**L**aptop)
- **DC:** Percentage of population with a **D**evice (**C**ar)
- **TP:** Es**T**imate of percentage of **P**hone users charging
- **TL:** Es**T**imate of percentage of **L**aptop users charging
- **TC:** Es**T**imate of percentage of **C**ar users charging
  - **EPP:** Daily **E**nergy consumption for **P**hones (**P**ower)
  - **ELP:** Daily **E**nergy consumption for **L**aptops (**P**ower)
  - **ECP:** Daily **E**nergy consumption for **C**ars (**P**ower)
    - **ETP:** Daily **E**nergy consumption **T**otal (**P**ower)
  - **EPC:** Daily **E**nergy cost for **P**hones (**C**ost)
  - **ELC:** Daily **E**nergy cost for **L**aptops (**C**ost)
  - **ECC:** Daily **E**nergy cost for **C**ars (**C**ost)
    - **ETC:** Daily **E**nergy cost **T**otal (**C**ost)

Deriving Values:

Environment Statistics

- Airport: **NA**
  - Today said that there are 62 commercial airports in the country of significant size; the Federal Aviation Administration defines medium and large airports as the majority, while the small airports only constitute 0.05 and 0.25% of the total passengers in the US[11].
    - N = (total annual number of fliers*(growth rate))/(total days in a year* number of commercial airports)
      (737.5*1000000*1.048)/(365.25*62)
      N = 32567
- Airport: **HA**
  - According to the Denver Business Journal, roughly 3 hours and 20 minutes are spent in an airport daily. **HA = 3.33 hr** [9].
- School: **NS**
  - Based on a table from the National Center of Education Statistics, the average American high school has a carrying capacity of **752** students, which is also the highest average against elementary and middle schools. Using the maximum average ensures the school calculation has the maximum annual energy fees [12].
- School: **HS**
  - According to a 2013 article by Business Insider, the average school day runs for six and a half hours, totalling to 1,170 hours in a year[13]. **HS = 6.5 hr**
- Cafe: **NC**
  - The average espresso drive-thru business (with sufficient visibility) sells **250** cups of coffee per day. This value was used to approximate the number of customers at a cafe over the course of a whole day[14]. **NC = 250.**
- Cafe: **HC**
  - Ignoring the consumers who immediately enter and exit the store, people spend various amounts of time in a cafe. Some people will stay for short meetings, others for long study breaks. Averaging these times makes an estimated **HC = 2 hr**

Non-Environment Statistics

- $ kW*H/H: **P**
  - For each device, the total energy charged was multiplied by the average daily energy costs for the device. As previously explained, the EIA database indicates that the price of a kilowatt per hour is $0.13 but the national sales revenue for commercial power is $0.11. The EIA has a database that lists the unit price for one kWh of energy in cents going from 1990 to present day, and when plotted can be summarized as its line of best fit, where y is the price and x is the year; y = 0.1329x-256.89. Plugging in 2019 returns a y value of $0.11[3].
    - y = 0.1329(2019) - 256.89
    - P = 11 (in cents)

- % of population with a Phone: **DP**
  - Based on the Pew Research Center of Internet and Technology, 96% of Americans own a cellphone, but only 81% have smartphones. Smartphones require more energy and are more frequently charged outside,[15] so **DP = 0.81**
- kW/Hr consumed by a Phone: **WP**
  - According to an Energy User Calculator[6], cell phone batteries use approximately 2 to 6 watts when charging based on the brand. Using the average power consumption will be generalize the model while retaining its accuracy. **WP = 0.004 kW/h.**
- % of population with a Laptop: **DL**
  - As published by the 2015 US Census [17], **74%** of Americans have a laptop.
- kW/Hr consumed by a Laptop: **WL**
  - According to Bijli BaChao [16], the typical laptop consumes 20 to 50 watts of energy while charging, but the amount can be trimmed down in power saver mode. The range depends on the type of screen, but since the model deals with the standard forms of each device, the average power consumption would be sufficient. **WL = 0.035 kW/h**
- % of population with a Electric Car: **DC**
  - Based on a recent study on the plug-in electric vehicles in the US [18], only 0.27% of cars on the road are electric.
- kW/Hr consumed by an Electric Car: **WC**
  - The average electric car battery is very distance-efficient and friendly to the environment. Battery University [4] says the standard electric car charges at 1.4 kWh. **WC= 1.4 kW/h**

As previously reasoned, smartphones, laptops and electric cars are respectively the most popular and energy consuming devices. However, the availability of public charging stations available for each device varies greatly.

Environment Charging Probability Estimates

- % of Phones charged: TP
  - % of Phones charged at an Airport: **TPA**
    - Due to its size and importance in communication, smartphones are the easiest device to charge; thus they will overall have the highest probability of being charged. Most outlets or charging stations are closer to convenient chairs and tables, and people wait a long time while charging as much as possible because there are no outlets on a plane. For an airport, **TP = 0.6**
  - % of Phones charged at a School: **TPS**
    - Most schools strictly forbid phone usage at any time, thus **TP = 0.2**
  - % of Phones charged at a Cafe: **TPC**
    - At cafes, customers are slightly more likely to use their laptop for productivity than their phone, so **TP = 0.4**
- % of Laptops charged: TL
  - % of Laptops charged at an Airport: **TLA**

        - Laptops are easy to charge, but difficult to maneuver in and out of the case in public settings, so **TLA is 0.4**
    - % of Laptops charged at a School: **TLS**
        - Laptops are easy to charge, but difficult to maneuver in and out of the case in public settings, so **TLS is 0.4**
    - % of Laptops charged at a Cafe: **TLC**
        - Consumers are likely to stay for a long time and work rather than temporarily wait or travel, so **TLC is 0.5**
- % of Electric Cars charged: TC
    - % of Electric Cars charged at an Airport: **TCA**
        - Most electric parking spots are present in some airports, as demonstrated by the electricity-dense LAX airports (LAX article). However, electric cars have power-efficient batteries, which are warranted for 100,000 miles, so **TCA = 0.25**
    - % of Electric Cars charged at a School: **TCS**
        - High schools have parking spaces for upperclassmen to drive to school; as electric cars become more popular, the price will decrease and more parking spaces will be made available. Currently, 0.27% of all American drivers have an electric car; therefore **TCS = 0.15**
    - % of Electric Cars charged at a Cafe: **TCC**
        - Cafes are often in plazas or have limited space, and it is exceedingly rare for a cafe to have designated spots for electric cars, so **TCC = 0.1**

Equations:

These are the variables and equations used in the computation Java Program (full code in Appendix)

QP = N*DP*TP
QL = N*DL*TL
QC = N*DC*TC

QP*WP*H = **EPP**
QL*WL*H = **ELP**
QC*WC*H = **ECP**

QP*WP*H*P = **EPC**
QL*WL*H*P = **ELC**
QC*WC*H*P = **ECC**

EPC + ELC + ECC = **ETC** (Total Daily Cost Across All Devices)

Assumptions:

- **The average energy consumption per hour of a smartphone is 0.004 kW, 0.035 kW for a laptop, and 1.4 kW for an electric car**
    - The smartphone, laptop and electric car are both the most popular and energy consuming devices that are accommodated frequently accommodated by public charging stations, let it be with outlets or charging stations. Other smart electronics, such as tablets, are usually kept within domestic domains and are inconvenient to carry in public spaces. Choosing these three devices for the model helps account for the variety in size and power of electronics being charged. In addition, different brands will have different hourly consumptions; since most data for a standard device is a range, using the averaged consumption per hour in our model minimizes deviations from accuracy when brand-specific statistics are applied but remains generalized enough emphasize the linear relationship between users and charging power.
- **Other devices being charged have negligible impact**

  - Other devices, such as tablets, are not as common as smartphones and laptops. They aren’t used as much in public, so the number of people charging such devices is negligible. Although there may not be as many electric vehicles as some other devices, the energy consumption from electric vehicles is significant, so it can’t be ignored. Other devices don’t have the same level of energy consumption, so they don’t need to be included.
- **Energy consumption is consistent from day to day**
  - There are typically fluctuations between consumers of any facility from day to day, especially between the weekend and weekdays. Holidays may also increase or decrease the number of consumers, but to generalize the model for any facility and any day, it is assumed that the energy usage and costs are the same per facility, and the averages eliminates the nuances between each day’s schedule.
- **A day is 365.25 days (to account for leap years)**
  - In order to preserve the dynamics of our model, the energy expenditure needs to be measured consistently for years. Every four years there will be a leap year, which has 366 days to synchronize the calendar year with the solar year, the length of time the Earth takes to orbit the sun. Standardizing the length of a year to 365.25 days does not make a significant change in the time in a year, while ensuring the computed annual energy costs are as consistent and accurate as possible.
- **Each person charges 1 or less of each type of device**
  - Most people will not be using multiple devices of the same type; if they are, they are unlikely to charge them all at once. However, they can be charging difference of devices at once because they are likely used for different purposes, especially when away from home.
- **All cables have devices attached to them**
  - Plugged-in cables still expend energy, but the quantity of energy being transported is more significant and easier to specify when there are devices attached to them. In addition, the probability of a person solely leaving a cable unattended is very low; most people prefer to keep track of as many belongings as possible and would not leave devices along without intent[7].
- **The charge times are the same as the average time people spend in the area**
  - When charging, most people don’t charge to precisely when their battery reaches 100%. Rather, they may charge until they have enough battery to unplug or may leave the device for some time, letting it charge on a full battery. Using the average time does assume that the charging time per person stays the same, but accounts for the range in charging times while quantifying unpredictable human behavior as much as possible.
- **Only the total number of people per day is considered**
  - The model first analyzes the total number of individual charges in a day, while assuming a constant rate energy supply over an averaged amount of time. The only value for annual electrical fees that matters is the daily cost of energy expended; this number already accounts for any abnormal charging patterns per person. Thus, statistics such as the number of people charging at once is irrelevant.
- **Number of outlets in a location is not considered**
  - The model focuses on the demand of the energy. Therefore, the number of outlets that a facility actually has, plays no role in determining the total demand for energy.

Model Prediction Values:

Sample Values for 2019:

NA = 32567 people
NS = 752 people
NC = 250 people

HA = 3.33 hours
HS = 2 hours
HC = 6.5 hours

P = $0.11 / kW*H

WA = 0.004 kW/H
WS = 0.035 kW/H
WC = 1.4 kW/H

DP = 0.81
DL = 0.74
DC = 0.0027

TPA = 0.6
TPS = 0.2
TPC = 0.4
TLA = 0.4
TLS = 0.4
TLC = 0.5
TCA = 0.25
TCS = 0.15
TCC = 0.1

Data Table for 2019:

Usage Numbers for 2019

In[∘]:=
```
Grid[{{"Environment", "Airport", "School", "Cafe"},
  {"Average Num. of People", 32 567, 752, 250}, {"Average Hours spent in Environment", 3.33, 2, 6.5},
  {"Average Num. of Phones charged", 15 828, 122, 81},
  {"Average Num. of Laptops charged", 9640, 222, 93},
  {"Average Num. of Electric Cars charged", 22, 0, 0}}, Frame → All]
```

Out[∘]=

Environment	Airport	School	Cafe
Average Num. of People	32 567	752	250
Average Hours spent in Environment	3.33	2	6.5
Average Num. of Phones charged	15 828	122	81
Average Num. of Laptops charged	9640	222	93
Average Num. of Electric Cars charged	22	0	0

Energy Consumption for 2019

In[∘]:=
```
Grid[{{"Environment", "Airport", "School", "Cafe"},
  {"Daily energy consumption by Phones", 210.82, 0.97, 0.65},
  {"Daily energy consumption by Laptops", 1123.52, 7.79, 6.48},
  {"Daily energy consumption by Electric Cars", 102.48, 0, 0},
  {"Total daily energy consumption", 1436.82, 9.61, 7.32},
  {"Total annual energy consumption", "524798.51", 3510.05, 2673.63}}, Frame → All]
```

Out[∘]=

Environment	Airport	School	Cafe
Daily energy consumption by Phones	210.82	0.97	0.65
Daily energy consumption by Laptops	1123.52	7.79	6.48
Daily energy consumption by Electric Cars	102.48	0	0
Total daily energy consumption	1436.82	9.61	7.32
Total annual energy consumption	524798.51	3510.05	2673.63

Energy Costs for 2019

In[∘]:=
```
Grid[{{"Environment", "Airport", "School", "Cafe"},
  {"Daily energy cost of Phones", "$23.19", "$0.11", "$0.07"},
  {"Daily energy cost of Laptops", "$123.59", "$0.86", "$0.71"},
  {"Daily energy cost of Electric Cars", "$11.27", "$0.00", "$0.00"},
  {"Total daily energy cost", "$158.05", "$1.06", "$0.8"},
  {"Total annual energy cost", "$57727.76", "$387.17", "292.20"}}, Frame → All]
```

Out[∘]=

Environment	Airport	School	Cafe
Daily energy cost of Phones	$23.19	$0.11	$0.07
Daily energy cost of Laptops	$123.59	$0.86	$0.71
Daily energy cost of Electric Cars	$11.27	$0.00	$0.00
Total daily energy cost	$158.05	$1.06	$0.8
Total annual energy cost	$57727.76	$387.17	292.20

Sample Values for 2030:

NA = 34609 people
NS = 799 people
NC = 264 people

HA = 3.33 hours
HS = 2 hours
HC = 6.5 hours

P = \$0.13 / kW*H

WA = 0.004 kW/H
WS = 0.035 kW/H
WC = 1.4 kW/H

DP = 1
DL = 0.74
DC = 0.054

TPA = 0.6
TPS = 0.2
TPC = 0.4
TLA = 0.4
TLS = 0.4
TLC = 0.5
TCA = 0.25
TCS = 0.15
TCC = 0.1

Data Table for 2030:

Usage Numbers for 2019

In[∘]:=

```
Grid [{{"Environment", "Airport", "School", "Cafe"},
  {"Average Num. of People", 34 609, 799, 264}, {"Average Hours spent in Environment", 3.33, 2, 6.5},
  {"Average Num. of Phones charged", 20 765, 160, 106},
  {"Average Num. of Laptops charged", 10 244, 237, 98},
  {"Average Num. of Electric Cars charged", 467, 6, 1}}, Frame → All]
```

Out[∘]=

Environment	Airport	School	Cafe
Average Num. of People	34 609	799	264
Average Hours spent in Environment	3.33	2	6.5
Average Num. of Phones charged	20 765	160	106
Average Num. of Laptops charged	10 244	237	98
Average Num. of Electric Cars charged	467	6	1

Energy Consumption for 2019

In[∘]:=

```
Grid [{{"Environment", "Airport", "School", "Cafe"},
  {"Daily energy consumption by Phones", 276.60, 4.15, 0.84},
  {"Daily energy consumption by Laptops", 1193.97, 53.8, 6.84},
  {"Daily energy consumption by Electric Cars", 2178.19, 116.84, 3.99},
  {"Total daily energy consumption", 3648.76, 116.84, 11.67},
  {"Total annual energy consumption", "1332709.59", "42675.81", 4262.27}}, Frame → All]
```

Out[∘]=

Environment	Airport	School	Cafe
Daily energy consumption by Phones	276.6	4.15	0.84
Daily energy consumption by Laptops	1193.97	53.8	6.84
Daily energy consumption by Electric Cars	2178.19	116.84	3.99
Total daily energy consumption	3648.76	116.84	11.67
Total annual energy consumption	1332709.59	42675.81	4262.27

Energy Costs for 2019

In[∘]:=

```
Grid [{{"Environment", "Airport", "School", "Cafe"},
  {"Daily energy cost of Phones", "$35.96", "$0.54", "$0.11"},
  {"Daily energy cost of Laptops", "$155.22", "$6.99", "$0.89"},
  {"Daily energy cost of Electric Cars", "$283.16", "$7.66", "$0.52"},
  {"Total daily energy cost", "$474.34", "$15.19", "$1.52"},
  {"Total annual energy cost", "$173253.69", "$5548.15", "555.18"}}, Frame → All]
```

Out[∘]=

Environment	Airport	School	Cafe
Daily energy cost of Phones	$35.96	$0.54	$0.11
Daily energy cost of Laptops	$155.22	$6.99	$0.89
Daily energy cost of Electric Cars	$283.16	$7.66	$0.52
Total daily energy cost	$474.34	$15.19	$1.52
Total annual energy cost	$173253.69	$5548.15	555.18

The percent of the population of 2030 was obtained by looking at the current trends of population growth in the US and extending that for the next 10 years. The percentage increase was also applied to each of the averages of the 3 locations to obtain the new average of the locations in 2030. The predicted population of the US by 2030 was used to get the new percentage of the population with certain devices by taking predicted users by the total population. Those numbers were applied to the model and new costs were calculated. The time spent charging was assumed to remain constant because only the number of devices is increasing.

Strengths and Weaknesses:

Strengths:

The model extends to other devices and adaptable for the future. The model is generalized, and for every device considered, primarily relies on knowing its power consumption, device quantity, and consumer usage patterns. As more technology is developed and popularized, the model can be adjusted after finding these three quantities.

Weaknesses:

The model maxes out the energy expenditure of "free" public charging stations. By assuming that every device present in the building will be charged, the system will know the maximum amount of money that could be spent on public charging in the year, thus being able to plan ahead of time for the worst - case scenario.

The model runs business-by-business. The derived values in the model are estimates for a casual, professional, and industrial places at three different sizes. Since most buildings fall into one of these categories or are similar in size, the model can estimate for most businesses. In addition, computing place by place means that the model is applicable for most buildings, assuming that the necessary statistics are regularly tracked.

The model requires specific information. The projections used in this model were specific to the United States, and requires averages for power consumption, the number of users likely to charge their device, the price of power, and the expected charging time.Some information is harder to find based on location.Unless these statistics are specifically found, the algorithm will not derive an accurate final value.

The model assumes devices charge the whole time a person is in a facility. Realistically, consumers are likely to charge one when necessary.The model becomes more precise as data is collected about charging times for each device.

The predicted growth assumes that the smartphone, laptop and electric cars are still the most popular devices. However, rapid advancements in augmented reality suggest that the smartphone will be irrelevant within the next decade; it is very difficult to predict the energy consumption and precise populations for each device. (smartphones obsolete)

The model assumes that every device that can be charged will be charged. Especially as the population grows, it is unrealistic to assume that every building will have enough chargers for all devices present to be charged.

Using averaged times does not account for abnormal schedules.Though the averaged time is an accurate estimate for the annual electrical fees, the model requires additional percentages to be accurate for small time frames, such as holidays or one week.

Potential Solutions:

Cost-Saving Initiatives:

- **Turn on power saving mode**
  - Many devices now have a power saving mode that conserves energy at the price of some performance capabilities. It is an effective way to reduce the amount of energy spent at public places, and therefore, reduces the amount of time needed to charge.
- **Unplug any devices at full battery or unused cables**
  - Fully charged devices will not be receiving any more energy, but will continue to use energy. Energy is wasted when plugs are not charging a device, so reducing the situations of this happening will cut down on wasted energy expenditures.
- **Monitor the amount of time a person charges a device**
  - For devices like electric car that need public charging stations, tools can be set up to control the amount of time a port supplies power to the vehicle or device. This method will keep devices from over charging.
- **Facilities can switch to cleaner energy**
  - Cleaner energy makes cheaper electricity with a higher initial cost. If companies are willing to switch to cleaner power sources, they may save money on energy in the long run.

Impact of Initiatives on the Model:

The model currently assumes that people are charging during their whole stay, but if their charging time is limited, that value may be changed to the average charging time of a device per person. Other constants like the cost of energy and the amount of energy used by each device will also change when the cost saving initiative are employed.The model process will remain consistent with the original scenario, but the numbers will adjust based on the change in the amount of time devices are charging and the cost of the energy.

Newspaper Article:

Energy: What's the Catch?

New research finds that the energy consumption is increasing. With the rapid improvements to smartphones, laptops, and electric cars, the need for "free energy" is increasing, and many public facilities, like our school, must compensate for this increase in demand. The projected cost of the increasing demand by 2030 is almost 3 times the current costs of "free energy."

So who pays for these costs? To enjoy the use of public power, a price must be paid. There are many ways to support public facilities that offer free energy to our phones, laptops, and cars. One possibility is to have public donations to support the communal use of power. This way, it is not necessary for everyone to pitch in, but those who do support the increased power demand for the rest of us. Our school can have a "Pay for Power" donation that allows the community to chip in all year round for the power fund. Another way for private businesses to support the increasing usage of electricity is to increase prices slightly. The overall cost of electricity is not expensive, so the few cents increase in the price of goods is enough to fund the electric bill. Even increasing all the prices in the store a little will allow the school to afford all the extra power we're using to charge our phones and laptops. The offer of free power is also enticing to more people and may bring more customers into the facility. Finally, for government funded buildings, taxes may need to be raised. Taxes are convenient and would ensure everyone is helping to fund the increased need for electricity. Based on the number of people currently at this school, we're expected to consume $2,200 a year. With either one of these methods or all of them, we can gather enough money to enjoy the benefits of public power.

Despite the increased demand power, there are ways we can limit the need for continuous public charging. There are ways to fund the increased energy usage, but it is still important to decrease the use of energy and save on expenses. Many devices have power saving modes that will decrease the power usage at the cost of some performance ability. This can help limit the excess power one needs while at a public facility. If everyone can turn their phones on power saving mode, the need to charge will decrease along with the bill. It is also recommended to unplug completely charged devices and unused cords. These devices can still consume electricity even while not charging, so to avoid wasting power, don't keep them plugged in. There may be measures that may be implemented to control the amount of time that devices can charge for or the battery percentage a device is charged to. This will avoid the problem of overcharging. Lastly, facilities can switch to renewable energy sources to provide energy to their building. Not only is it free once implemented, it is better for the environment.

Our hunger for power is growing, and we must find a way to satiate it. The benefits and consequences will be felt by everyone, so it on us to support our spending. It's important to act early and spread awareness. Let our school be the first one to encourage the public availability of energy and the sustainable practice to fund it.

Appendix:

This Java program, created by Team 9540, computes the daily energy expenditures at each designated location with the three key devices, and was used to check the accuracy of computations and calculate projected 2030 values.

```
public class HiMCM {

public static void main (String [] args) {

          // # of people
          double N = 111978;

          // # of hours
          double H = 3.33;

          // $ per KW*H
          double P = 0.11;

          // KW/hr for Phone
          double WP = 0.004;

          //KW/hr for Laptop
          double WL = 0.035;

          //KW/hr for Electric Car
          double WC = 1.4;

          // % population with Phone
          double DP = 0.81;

          // % population with Laptop
          double DL = 0.74;

          // % population with Electric Car
          double DC = 0.0027;

          // % population charging Phone
          double TP = 0.6;

          // % population charging Laptop
```

```
            double TL = 0.4;

            // % population charging Electric Car
            double TC = 0.25;

            // Energy
            double EPP = getPhoneEnergy(N,H,WP,DP,TP);
            System.out.println (“The daily energy consumption for phones is “ + EPP + “ kilowatts \n”);

            double ELP = getLaptopEnergy(N,H,WL,DL,TL);
            System.out.println (“The daily energy consumption for laptops is “ + ELP + “ kilowatts \n”);

            double ECP = getCarEnergy(N,H,WC,DC,TC);
            System.out.println (“The daily energy consumption for electric cars is “ + ECP + “ kilowatts
    \n”);;

            double ETP = get Total Energy(EPP,ELP,ECP);
            System.out.println (“The total daily energy consumption is “ + ETP + “ kilowatts \n”);
            System.out.println (“The total annual energy consumption is
    “+Math.round((ETP*365.25)*100.0)/100.0 + “ kilowatts \n”);

            // Cost
            double EPC = getPhoneCost(N,H,P,WP,DP,TP);
            System.out.println (“The daily cost for phones is $” + EPC + “\n”);

            double ELC = getLaptopCost(N,H,P,WL,DL,TL);
            System.out.println (“The daily cost for laptops is $” + ELC + “\n”);

            double ECC = getCarCost(N,H,P,WC,DC,TC);
            System.out.println (“The daily cost for electric cars is $” + ECC + “\n”);

            double ETC = getTotalCost(EPC,ELC,ECC);
                System.out.println (“The total daily cost is $” + ETC + “\n”);
            System.out.println (“The total annual cost is $” + Math.round((ETC*365.25)*100.0)/100.0);

        }


        private static double getPhoneEnergy (double N, double H, double WP, double DP, double TP) {

            double QP = N*TP*DP;
```

```
			double EPP = Math.round(QP*WP*H*100.0)/100.0;
			return EPP;
		}

		private static double getPhoneCost (double N, double H, double P, double WP, double DP, double
	TP) {
			double QP = N*TP*DP;
			double EPC = Math.round(QP*WP*H*P*100.0)/100.0;
			return EPC;
		}

		private static double getLaptopEnergy (double N, double H, double WL, double DL, double TL) {
			double QL = N*TL*DL;
			double ELP = Math.round(QL*WL*H*100.0)/100.0;
			return ELP;
		}

		private static double getLaptopCost (double N, double H, double P, double WL, double DL, double
	TL) {
			double QL = N*TL*DL;
			double ELC = Math.round(QL*WL*H*P*100.0)/100.0;
			return ELC;
		}

		private static double getCarEnergy (double N, double H, double WC, double DC, double TC) {
			double QC = N*TC*DC;
			double ECP = Math.round(QC*WC*H*100.0)/100.0;
			return ECP;
		}

		private static double getCarCost (double N, double H, double P, double WC, double DC, double TC)
	{
			double QC = N*TC*DC;
			double ECC = Math.round(QC*WC*H*P*100.0)/100.0;
			return ECC;
		}

		private static double getTotalEnergy (double EPP, double ELP, double ECP) {
			double ETP = Math.round((EPP + ELP + ECP)*100.0)/100.0;
			return ETP;
		}
```

```
    private static double getTotalCost (double EPC, double ELC, double ECC) {
        double ETC = Math.round((EPC + ELC + ECC)*100.0)/100.0;
        return ETC;
    }
}
```

In addition, the EIA provided a database with the average cost of energy in cents from 1990 to now, however the table was over 18,000 rows long. Averages were derived from the database, and are listed below.

```
centskWh =
  Import["/Users/            /Pictures/cents kWh.xlsx", "HeaderLines" → 12];

In[50]:= Text[Grid[Prepend[centskWh[[1]], {"Year", "Cents per kWh"}],
  Alignment → Center, Dividers → {{2 → True}, 2 → True}, Spacings → {1, 1}]]
```

Out[50]=

Year	Cents per kWh
2001.	7.2369
2002.	7.13005
2003.	7.33464
2004.	7.54654
2005.	8.08554
2006.	8.83788
2007.	9.1865
2008.	9.97792
2009.	9.93546
2010.	10.0823
2011.	10.2922
2012.	10.3229
2013.	10.5701
2014.	10.9497
2015.	10.9083
2016.	10.7992
2017.	11.0467
2018.	11.2094
2019.	11.3308

Finally, the EIA provided a database with the energy net generation, in billions kWh, from 1950 to now, however the table was over 18, 000 tables long. Averages were derived from the database, and are listed below.

```
electricityGeneration = Import[
   "/Users/            /Pictures/electricityGeneration.xlsx", "HeaderLines" → 2];
```

```
In[60]:= Text[Grid[Prepend[electricityGeneration[[1]],
            {"Year", "Electricity Generation, Billion kWh"}],
          Alignment → Center, Dividers → {{2 → True}, 2 → True}, Spacings → {1, 1}]]
```

```
Year  | Electricity Generation, Billion kWh
------+------------------------------------
1949. |        296.124
1950. |        334.088
1951. |        375.298
1952. |        403.829
1953. |        447.049
1954. |        476.258
1955. |        550.299
1956. |        603.876
1957. |        634.642
1958. |        648.451
1959. |        713.379
1960. |        759.156
1961. |        797.124
1962. |        857.944
1963. |        920.028
1964. |        987.218
1965. |        1058.39
1966. |        1147.53
1967. |         1217.8
1968. |        1332.83
1969. |        1445.46
1970. |        1535.11
1971. |        1615.85
1972. |        1752.98
1973. |        1864.06
1974. |        1870.32
1975. |        1920.76
1976. |        2040.91
1977. |        2127.45
```

```
         1978. | 2209.38
         1979. | 2250.67
         1980. |  2289.6
         1981. | 2297.97
         1982. | 2244.37
Out[60]= 1983. | 2313.45
         1984. | 2419.47
         1985. |   2473.
         1986. | 2490.47
         1987. | 2575.29
         1988. | 2707.41
         1989. | 2967.15
         1990. | 3037.83
         1991. |  3073.8
         1992. | 3083.88
         1993. | 3197.19
         1994. | 3247.52
         1995. | 3353.49
         1996. | 3444.19
         1997. | 3492.17
         1998. |  3620.3
         1999. | 3694.81
         2000. | 3802.11
         2001. | 3736.64
         2002. | 3858.45
         2003. | 3883.19
         2004. | 3970.56
         2005. | 4055.42
         2006. |  4064.7
         2007. | 4156.75
         2008. | 4119.39
         2009. | 3950.33
         2010. | 4125.06
         2011. | 4100.14
         2012. | 4047.77
```

2013.	4065.96
2014.	4093.61
2015.	4077.6
2016.	4076.68
2017.	4034.27
2018.	4177.81

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