Summary Statement – Team # 5261

The United States has undergone a massive transformation in the way it approaches telecommunications. In 30 years, it has gone from having an entirely land-line based phone system to one where 89.2% of the population uses cell phones, with 16.4% of households having replaced their landlines entirely. With these figures in mind, we set out to establish the key consequences and energy costs of this American phone system.

By collecting data on wattages of cell phone rechargers and modeling likely American cell usage, we calculated that a cell might waste 86% of its energy intake through its charger: that results in 753,500 barrels of oil being wasted per year total. Using this information, compared to the energetic costs of landline phones, we model two transition scenarios as cell phones replace land lines in the United States. We concluded that the faster landlines can be phased out, the more energy the U.S. will save, as cordless landline phones actually consume much more energy than cells.

Considering these facts, we found that a full cell network, combined with voice over internet protocol technology (VOIP), would be the best way to provide phone service to a Pseudo U.S. completely lacking in telecommunications. This would save the cost of the implementation of a landline infrastructure that would be rendered mostly redundant as cell phones became more popular. Because all the cell rechargers in this Pseudo U.S. would be brand new models with recent energy conservation features, cell phone waste would only add up to 234,100 barrels of oil annually. We modeled the increase in cell phone energy consumption in this Pseudo U.S. for the next 50 years with two models: one that accounts for the growth of the country, and another that also factors in a reasonable rate of technological advancement. In the first model, cell energy consumption would reach 1.53 million barrels of oil per year by 2059, while in the second, it would actually decrease to 525,000 barrels of oil by that time due to increases in battery efficiency and a reduction in standby power.

Cell phone rechargers are only one small part of a large picture of standby power waste in America. Using extensive wattage and usage data on consumer electronics, we calculated that these devices waste 99.4 million barrels of oil in energy annually.

These models show that although a single cell phone charger may waste only a small amount of energy (one author estimates leaving a charger plugged in for a day is about equal to driving a car for one second), the shear magnitude of cell phone users means that this loss is significant and deserves recognition and concern in the public eye.

Energy Implications of Cellular Proliferation in the United States

Since the introduction of cell phones to the United States, their usage among the American public has grown exponentially. They are convenient, portable, increasingly versatile, and in many instances essential to supporting the lifestyles of American citizens. That being said, there is a significant problem with our current system: overindulgent energy consumption. To address this issue, we will discuss the various electricity costs during a cell phone's life. Further, relative energy use of cell phones and landlines will be analyzed, and the transitional currently occurring between cells and landlines will be modeled. Using this information, we will develop an energetically optimized phone system for an emerging country much like the United States, and calculate the potential waste energy lost by cell phones in this new system. Next, we will project the costs of telecommunications in the country as it grows for the next fifty years. Finally, we will analyze power lost by other types of consumer electronics that rely on rechargers and plugs, like laptops, televisions, and DVD players.

SECTION 1: Wasted Electricity Due to Cell Phone Rechargers

To approach the energy cost of mobile phones, we first considered the energy consumption of a single cell phone. This comes in two varieties – the energy needed to recharge the cell phone and the energy that leaks from the charger when it is left plugged into the wall. To find the energy lost as leakage from cell phone chargers, we first had to determine the wattage that is being lost during this state. David MacKay, the author of a book on sustainable energy use, convinced two members of the Cambridge University Engineering Department to measure a standard Nokia phone recharger in a calorimeter – a much more accurate technique than anything we could devise. This method reported 0.472 W being drawn while only the charger was plugged into the wall, 0.845 W wasted when a fully charged phone was left attached, and interestingly, 4.146 W lost as heat even while the phone was charging. MacKay also suspects that older phone chargers may use one to three watts[1]. Another source reported 2.77 W consumed by a phone charger while it was charging, and 0.45 W consumed while it was not[2]. A page on brand new Motorola chargers listed their standby wattage as about 0.2[3]. As MacKay's experiment showed the charger drawing about twice as much power with the phone attached as it did without the phone, we assumed that these brand new chargers would do the same.

Once we knew the wattages of old phone chargers (about 2 W without a phone attached and 3 W with a phone), fairly new phone chargers (0.472 W without a phone attached, 0.845 W with a phone), and brand new phone chargers (0.2 W without a phone attached, and probably about 0.4 W with a phone), we only had to make a few suppositions about the number of each type of phone charger in use in the U.S. today. This task was made easier by the knowledge that the average cell phone is replaced every 18 months[4]. It seems likely that the fairly new models

[1] "Sustainable Energy – without the hot air," David MacKay
[2] IP.com
[3] "Charger Energy Efficiency," Motorola.com
[4] Dawn Stover, MSNBC, "Wireless Recycling Frequently Asked Questions," ReCellular, and "Cellular Recycling Facts," Recycling for Charities

and brand new models will be present in approximately equal numbers, while both will outnumber the older, leakier chargers. If we assume that 20% of phone chargers are old or cheap, 40% use about 0.472 W, and 40% do not leak at all, then the average cell phone charger wastes about 0.589 W while left plugged in without a phone and 0.938 W while left plugged in to a fully charged phone.

Next we need to consider how long the charger is in each of these states. We constructed a model using two equations. The first covers those who unplug their phone and their charger at the same time: (x)(y(0.938 W)), where x is the number of times they recharge their phone a year, and y is the average amount of time they leave their phone plugged in after it has reached full charge in hours. The second equation is aimed at those who unplug their phone from the charger, but leave the charger plugged in. We assume that those who don't unplug the charger right away once their phone is charged will rarely come back to unplug just their charger at a later date – perhaps a few times a year when they need the outlet, but not consistently. Thus, the equation is: (x)(y(0.938 W))+(0.589 W)(8760-300-xy). Here we have kept the first equation (because this energy is still lost), and simply added on the rate of waste while just the charger is plugged in (0.589 W), times the number of hours in a year (8760), minus the average time a phone would need to charge a year (300 hours). We also had to subtract out (xy), to account for the hours the phone would still be attached to the charger after it was charged, leaking power at 0.938 W instead of 0.589 W.

Now we just need to weigh the two equations according to how many people we feel fit in each category, decide how many times an American recharges their phone on average, and decide how long they usually leave their cell plugged in after it has reached full charge. We supposed that 75% of Americans unplug only their phone and leave the charger in the wall, while the other 25% unplug both once they realize their phone is charged. From browsing a few pages of cell phone specs, we found average talk time to be around 5 hours, and average standby time to be about 10 days[5]. If the average American uses their cell for talking, texting, or other uses an hour a day, in three days they would have used up 60% of their battery through activity (3 hours/5 hours), and 30% of their battery to standby (3 days/10 days). So, we assume that the average American would only *have* to recharge their battery about 100 times a year (121 if they recharged it every three days, but after three days it would still have 10% of its charge left). On the other hand, many Americans plug in their phones every time they come home, in effect recharging their phone 365 times a year. We plugged both of these numbers into our model to see their effect on total energy consumption.

We also chose 2 hours and 6 hours as two likely averages for how long Americans leave their phone plugged in after it is charged, as some might leave their phone plugged in all night, producing 6-9 hours of waste after an hour of charge, while others might unplug the phone within minutes. Because we needed a single number for our models in Section 2, we selected 175 recharges a year and 4.5 hours left plugged in after charging as suitable averages. In the table below, the average time the user left the phone plugged in after it was fully charged is recorded along the top, and the number of times the phone was charged is recorded along the left side.

[5] "Cell Phones and Devices," AT&T

	2 hours	4.5 hours	6 hours
100 recharges	1.186 TWh		1.251 TWh
175 recharges		1.281 TWh	
365 recharges	1.272 TWh		1.509 TWh

From these five scenarios, it appears that 1.281 TWh, or 753,500 barrels of oil (1700 kWh = 1 barrel), is a fair estimation of the average waste produced by American cell phone chargers in a year. Changing either of the two variables does not have a serious effect. But then how could we reduce waste? To find out, we constructed a second table, this one assuming that every single American cell phone user gets into the habit of unplugging their charger as they unplug their phone.

	2 hours	4.5 hours	6 hours
100 recharges	0.06 TWh		0.179 TWh
175 recharges		0.235 TWh	
365 recharges	0.218 TWh		0.654 TWh

Clearly this is the first tendency to change. The vast majority of cell phone standby power waste is coming from those who only unplug their phone. If everyone unplugged their phone and charger at the same time, waste would be cut by 65-95%, depending on the other two factors. The constant power drain of the charger plugged in to the wall simply outweighs other factors like number of recharges or how long the phone is left plugged in.

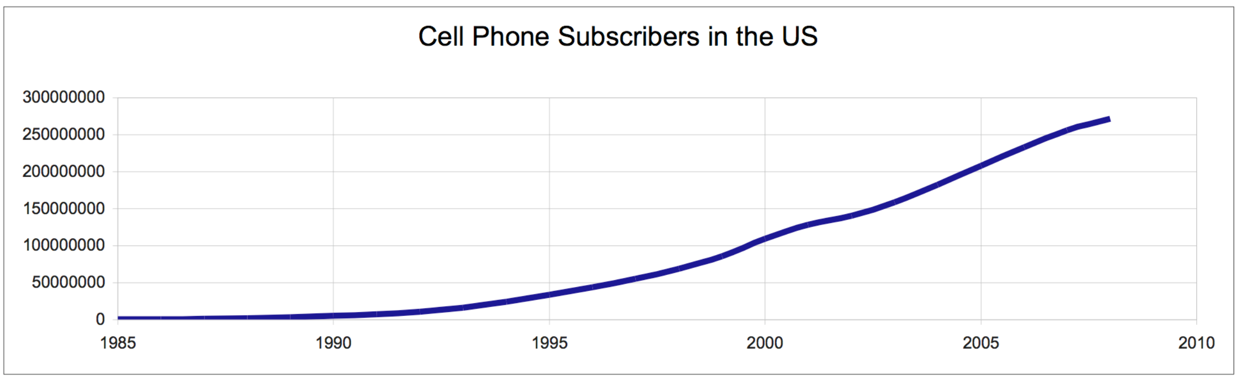
In terms of the energy required to keep a single cell phone charged throughout the year, we decided that on average, a phone would need to be recharged for 300 hours a year. This was estimated by multiplying our 100 recharges a year estimate by 3 hours per recharge – numbers we felt accurately reflected the needed recharge time. We determined that the average phone would charge at 3 W by averaging a table of modern phone wattages, many of which were in range of 1 W[6], and the wattages of older generation phones, which we assumed must have higher wattages, due to MacKay's measurement of over 4 W lost as heat during charging[7]. We multiplied this times 3 W, which we calculated as the average wattage at which cell phones recharge, to get 0.9 kWh used in a year to charge a single cell phone. When combined with the 4.713 kWh of waste per phone we determined above, this means that 84% of the energy used on cell phones is wasted, which nicely splits the difference between 3-year old statistics we found (95% lost as waste[8]) and statistics from only two months ago (67% lost as waste[9]). This makes sense, as we already found that brand new phones lost less energy to standby power, while older phones are more wasteful. Our number appears to be a nice average that takes into account both old phones, phones of medium age, and new phones.

Now that we know how much energy an average cell phone consumes in a year – 5.613 kWh – we can calculate the effect of the proliferation of cell phones through America, as they replace landlines.

[6] "Cell Phones and Devices," AT&T
[7] David MacKay
[8] Micheal Graham Richard, Treehugger.
[9] Tarmo Virki, Reuters.

SECTION 2: US Transition From Landlines to Cell Phones

The United States presents an interesting case study of the relative energy efficiency and usage of landlines versus cell phones. Since the introduction of the cell phone, their popularity has grown exponentially (see graph below). As of February 7, 2009, there were 271,778,000 cell phone subscribers[10] in the United States, and while this number continues to grow, the number of households using landlines is on a sharp decline. Between 2004 and 2008, the percentage of cell-only households in the United States rose from 4.5% to 16.4%[11]. We will now analyze the transition from the current system of a mixture of cell phones and landlines to a system consisting of exclusively cell phones. In order to do this, we have developed two models for the transitional phase. Based upon these models we will evaluate the relative energy costs of each type of transition, and discuss the most efficient route for obtaining an exclusively cell phone communication system.



In considering the total energy costs of cell phones, there several different factors. The first, and most obvious, is the energy needed to keep the phone battery charged on a continual basis. There is also the production cost of each cell phone in terms of energy. This quantity is extremely variable and poorly documented in terms of energy usage. So, while we could roughly estimate the average energy needed to produce a cell phone or a cordless phone, we felt it was more worthwhile to concentrate on the legitimized data concerning the charging of cell phones and cordless phones. In terms of the relative costs of production, we do know that since each cell phone has a life of approximately 1.5 years[12], compared to the 6 year average lifespan of a cordless telephone. If we assume the energy used to produce both types of phones is comparable, over a given time period, the production costs of cell phones will be four times that of cordless phones. The last major form of energy consumption due to cell phone usage is that of the cell towers themselves. We will delve into a discussion of how many additional cell towers will be needed to support the growing number of cell subscribers, and also analyze some of the energy costs of maintaining the land-line system.

[10] CTIA.org
[11] Kim Dixon, Reuters.
[12] Dawn Stover, MSNBC, “Wireless Recycling Frequently Asked Questions,” ReCellular, and “Cellular Recycling Facts,” Recycling for Charities

Our primary focus in the ensuing models will concern the relative energy costs of keeping cell phones and cordless phones charged and usable. We would like to incorporate the other aspects of energy costs into our model, but the lack of reliable data would create an error large enough to render the model extremely unlikely. Thus, we will tackle the problem at hand from the standpoint of energy usage when in the hands of the consumer.

-Basic Information and Assumptions

Before we jump into our first model of this system, we need to establish the initial conditions for the transition from landlines to cell phones. For this problem we are asked to assume that the population of the United States is approximately 300 million. The actual population of the United States as of the end of 2008 is around 305 million[13]. For the sake of accuracy, we will use the actual population for all further calculations.

We have found that approximately 2.5%[14] of US households use neither landline nor cell phones. Thus, for our models, we will assume that a complete transition from landlines to cell phones will in result in 97.5% of the population having cell phones, since the variance in household size, based upon demographic information, is negligible on such a large scale. Put simply, everyone who wants to have access to a phone will have one at this percentage. What this means for us is that since there are 111.1 million households in the US[15], 108.3 million households require some form of phone line. In 2008, 16.4% of total households opted to use only cell phones. Thus since we have 97.5% of the population using some form of phone, the number of households using landlines in 2008 is:

$$\mathbf{H} = (.975 - .164)*111.1 = \mathbf{90.1\ million\ households}$$

Furthermore, we have found that the average number of people per household is **m = 2.745**. However, this data is only part of what we need.

The problem becomes a bit more complicated when we consider what it actually means to provide each member of every household with a cell phone. There are two primary concerns. First of all, with this transition, we are assuming that every man, woman, and child receives a cell phone. However, approximately 6.9%[16] of the US population is under the age of 5, which equates to 21 million children. There is little or no reason to provide these children with cell phones. Considering this data, if we remove these 21 million children from the number of subscribers, the United States would be very close to achieving a complete transition already. If we assume a starting population of 305 million and the number of cell subscribers as 272 million, that leaves us with 33 million US citizens to supply with cell phones. However, if we remove the 21 million children under five from this list, we need only supply 12 million more cell phones, which certainly could be done in a matter of a couple years if necessary.

The second problem lies with the data for current cell phone users. We know that there are approximately 272 million cell phone subscribers currently in the United States. However, this number does not account for people who hold more than one account – namely people who have a personal cell phone and a work cell phone. In fact, there is hardly any data on the number

[13] "Population Clocks," Census Bureau.
[14] Maureen Bavdek, Reuters.
[15] Census Bureau.
[16] Census Bureau .

of people who fall into this category, and the information we *have* found cannot be corroborated. Thus, we will assume that these multiple-phone users have a negligible effect on the total number of cell users in the US, and continue to use 272 million cell phone subscriptions as our starting point.

-Preliminary Data on Cell and Cordless Phone Energy Use

In order to accurately model the energy costs of the phone system in the United States, we needed to establish a few important quantities. Throughout our research we have discovered a large amount of information pertaining to three types of phones – cell, cordless home phone, and corded home phone. In order to establish the energy "costs" of each of these three types of phone, we needed to calculate five specific pieces of data:

$E_{production}$ = Energy Used to Produce Each Type of Phone
$E_{support}$ = Energy to Support Each Type of Phone per Year
E_{charge} = Energy Used to Charge/Power Each Type of Phone per Year
LS = Average Lifespan of each Type of Phone
N = Number of Each Type of Phone Being Use

The first two pieces of data – $E_{production}$ and $E_{support}$ – are nearly impossible to find to any degree of accuracy. There is a great deal of information available concerning costs of materials and overall monetary cost to manufacture a given phone, but the *energy* that goes into actually producing a given phone is unknown. So, we will make the assumption that it takes the same amount of energy to produce a cell phone and a cordless phone. The number of corded phones currently being sold is negligible.

Likewise, the energy that goes into phone support – energy costs of cell tower construction, tower and landline upkeep, signals, etc. – is not well documented. We found two rough estimates – the first, that 0.12% of global primary energy use is used by telecom companies.[17] If this proportion holds true for the U.S., which uses 3,923 TWh a year,[18] then U.S. telecom companies consume 470 TWh per year. This does not tell us whether or not this energy is going towards landlines or cell phones, but it does give an idea of the scale – much larger than energy consumed by cell phones. A second estimate, gathered from quarterly reports, was that Japanese mobile telecommunications companies use 120 Wh per user per day[19]. If American mobile companies did the same, this would equal 11.9 TWh per year. These numbers contradict each other – we find it hard to believe that telecom company might spend about 40 times more energy on non-cellular aspects of its business as it does on mobile infrastructure. However, more accurate data is simply not available[20]. Since these two quantities cannot be accurately determined, we have taken the remaining three variables to use in our models of electricity utilization during the transitional phase as well as the subsequent steady state of equilibrium. KWh used by the average cell phone was found to be 5.613 kWh, as described in section 1, by

[17] "Sustainable energy use in mobile communications," Ericcson.
[18] "Electricity Basic Statistics," Energy Information Association.
[19] Minoru Etoh.
[20] This quantity could be attainable outside of the parameters of this competition if we could obtain a quote for construction costs and energy uses from a company that constructs cell towers or lays landlines.

adding the 4.713 kWh of waste per phone that we calculated in Section 1 to 0.9 kWh, representing 300 hours per year of charging at an average of 3 W. The 28 kWh used per cordless phone was taken from a TIAX LLC. study on the power consumption of consumer electronics which will be discussed in detail in the consumer electronics section at the end of the paper[21]. The 2.2 kWh for the corded phones was estimated by multiplying 0.25 W (every source we found said that corded phones used a “smidgen” or a “dab” of power running through the phone line, but this number must be greater than 0 W) by the number of hours in a year, 8760. Average lifespan of a cell phone (determined by consumer replacement rate, not breakdown rate) was gathered from a number of sources[22], while the lifespan of cordless and corded was estimated. We also estimated that there were two cordless landline phone for every one corded landline phone.

	E_{charge} (kWh)	LS (Years)	N
Cell Phone	5.613	1.5	x
Cordless	28	6	0.667(y)
Corded	2.2	10	0.333(y)

As the reader can see from this table, the primary concern now becomes calculating the number of each type of phone in use at a given period in time. In order to help us with these calculations, we have developed two models to describe the relative changes in the number of cell phones to the number of landline phones.

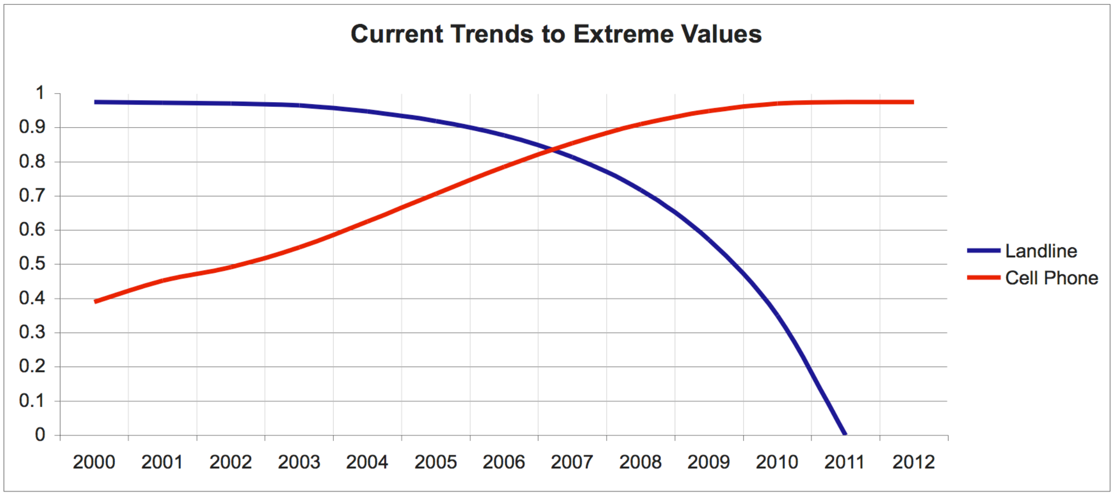
-Model 1: Current Trends

If we examine the current trends of cell phone usage in the United States, we can establish a reasonable timetable for the transition between landlines and cell phones. For our first model, we will assume that the current trends will continue unimpeded and unchanged until we reach a state of 97.5% of people having cell phones (all those who desire a phone have one) and 0% of people using landlines. Using data since 2000, we can construct the following trends[23]:

[21] Roth and McKenney, TIAX LLC.

[22] Dawn Stover, MSNBC, “Wireless Recycling Frequently Asked Questions,” ReCellular, and “Cellphone Recycling Facts,” Recycling for Charities

[23] Landline data from “Call My Cell: Wireless Substitution in the United States,” Nielsen. Cell data from “Cell Phone Subscribers in the U.S., 1985-2005,” Infoplease.com, originally from CTIA – The Wireless Association.



For the sake of consistency between our two models, we will calculate the total energy consumption due to phone usage by the American public between 2009 and 2015 for each model.

In order to calculate the total energy used to charge all of the cell phones in the US as well as power all of the corded and cordless landline telephones, we need to first find the respective areas under the curve of our two lines between 2008 and 2015. To calculate the area under the curve, we plotted our most recent data and constructed a projection based upon the current trend of the respective percentages of phone usage. After doing this, we acquired the best-fit trend-line for each projection and determined its equation. So, with the equation we simply took the integral of the curve over our time period, with 2008 as the lower bound and 2015 as the upper bound. This integral gives us the average % of the population that has a cell phone each year, times the number of years we are considering (7). Now, if we consider that fact that the average cell phone uses 5.613 kWh per year and the average landline phone uses 19.4 kWh per year[24], our equation for total energy used by phones between 2008 and 2015 becomes:

$$E_{phone} = (AveragePopulation) * \left[\int_{2008}^{2015} (\%Equation)\right] * \left(\frac{Phone\ Energy\ Used}{Year}\right)$$

$$E_{cell_1} = (313100000) * \left[\int_{2008}^{2015} (\%\ Cell\ Equation_1)\right] * \left(5.613\ \frac{kWh}{Year}\right) = 11.4\ \ TWh$$

$$E_{landline\ phone_1} = (313100000) * \left[\int_{2008}^{2015} (\%\ Landline\ Equation_1)\right] * \left(19.4\ \frac{kWh}{Year}\right) = 7.9\ \ TWh$$

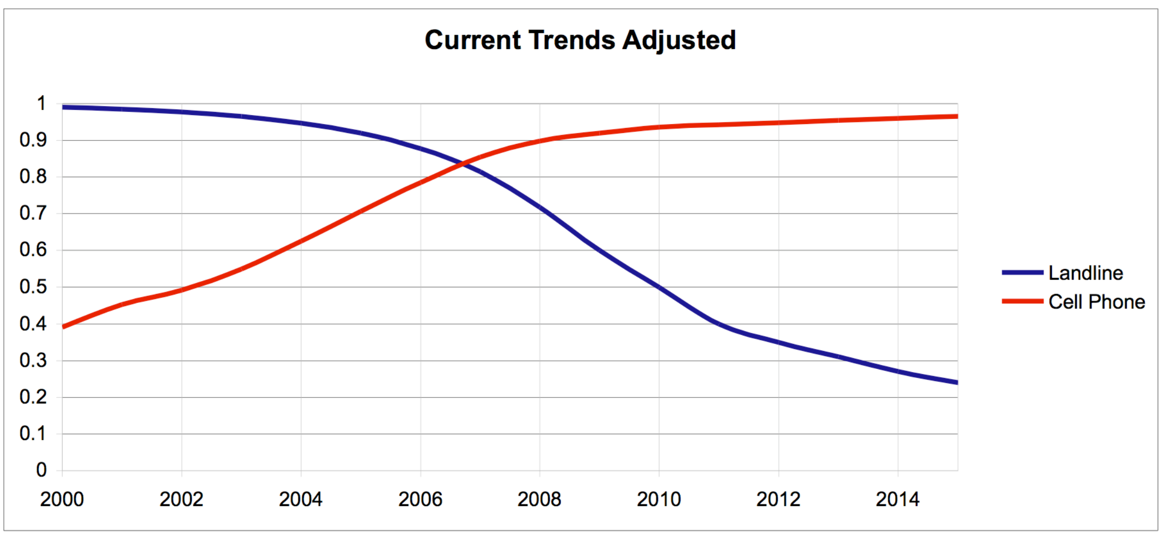
$$E_{tot}(Model\ 1) = 11.4\ \ TWh + 7.9\ \ TWh = 19.3\ TWh$$

[24] A weighting of the average kWh/year of cordless phones (28), and corded phones (2.2), assuming there are twice as many cordless phones as corded.

Thus, the total amount of energy used by cell phones, corded phones, and cordless phones between now and 2015 is 19.3 TWh. If each person in the US (technically 97.5%) had a cell phone and no landline phones were used, the total energy used would be approximately 12 TWh.

-Model 2: Current Trends with Resistance to Extremes

Model 1 works nicely if we assume that the current trends will continue until the landline becomes extinct, but in all probability, this is not what will actually happen. It is probable that cell phone usage will creep very close to our maximal 97.5% of the population line, but there are several reasons why landline usage will not drop to 0%. Many people feel more comfortable with the added security of a landline to use, if for some reason their cell phone is not working. Landline phones are generally easier to talk on for long periods of time, and there is also the current worry that cell phones may cause cancer to factor into the equation. Also, when we consider senior citizens, who tend to be slightly more resistant to technological changes, it becomes apparent that a substantial percentage of American citizens may opt to stay with a landline as long as it is available. Using information from several different polls concerning the public's feelings about having a landline for backup and practical purposes, we have established a second model that accounts for this resistance to change.



Using this model, we can now calculate the total energy used by phones between 2008 and 2015. We will use the same equation as in Model 1 above:

$$E_{phone} = (AveragePopulation) * \left[\int_{2008}^{2015} (\%Equation)\right] * \left(\frac{Phone\ Energy\ Used}{Year}\right)$$

$$E_{cell_2} = (313100000) * \left[\int_{2008}^{2015} (\%\ Cell\ Equation_2)\right] * \left(5.613\ \frac{kWh}{Year}\right) = 11.25\ \ TWh$$

$$E_{landline\ phone_2} = (313100000) * \left[\int_{2008}^{2015} (\%\ Landline\ Equation_2)\right] * \left(19.4\ \frac{kWh}{Year}\right) = 17.6\ \ TWh$$

$$E_{tot}(Model\ 2) = 11.25\ \ TWh + 17.6\ \ TWh = 28.85\ TWh$$

Thus, with Model 2, we see a total of 28.85 TWh being used in the next seven years with the current mixture of cell phones and landline cordless and corded phone. Obviously, this is an extremely wasteful practice to have both systems running simultaneously. For again, if the United States was restricted to only cell phones, the energy used over the same time period would be 12 TWh.

Obviously, at some point if the number of landline users drops to a minimal level, it will no longer be profitable for landline service providers to stay in business. However, we feel that as long as there are those who are willing to continue to pay for their service, and the cost of upkeep on landlines remains minimal, there will continue to be some form of landline usage in the United States. From an energy standpoint, this does not make any sense, but in order for there to be a complete transition from landlines to cell phones, it would require some sort of governmental intervention, or a collapse of the landline industry.

-Summary of Section 2

These two models exemplify the predicted modes of transition from landline phones to entirely cell phones. We see that when the transformation is complete, the system using only cell phones is actually more energy efficient than the current system of overlapped usage of cells and landlines. If we consider the energy costs of cell phones and landlines put together based upon relative usage trends between 2008 and 2015, we find that:

	E_{cell} (TWh)	$E_{landline}$ (TWh)	E_{total} (TWh)
Instant Transformation (All Cells)	12	0	12
Model 1 Current Trends Extended	11.4	7.9	19.3
Model 2 Current Trends Corrected	11.25	17.6	28.85

The longer it takes for landlines to be phased out, the more energy the U.S. loses. This is somewhat unfortunate, considering the undeniable efficiency and reliability of a corded phone. However, the cell is here to stay, and once nearly every American has a cell phone, it just doesn't make energetic sense to operate two redundant systems.

SECTION 3: Bringing Phone Service to the "Pseudo US"

We now consider a second scenario – that of a "Pseudo US." We assume this country has the exact same population, economic status, and infrastructure as the United States. However, there will be no initial phone system in place. Our goal is to devise a strategy for the implementation of a phone system that minimizes energy usage, while still compensating for the needs of the general population. Obviously, there are several socioeconomic factors at play, and in addition to providing a detailed analysis of our energy efficient phone system, we will discuss the consequences of all current types of phone systems: landlines, cell phones, satellite phones, voice over internet protocol technology (VOIP) and logical combinations of these services.

Certainly, using only landlines connected to corded phones would be a very energetically cheap technique. As we showed in Section 2, corded phones use less energy than cell phones, drawing only a tiny amount of power through the phone lines. A landline only system would also have lower maintenance costs from the provider's standpoint – mostly just passive wiring instead of active cell towers to power and repair. Phones would also be broken or lost less often, and there would be far less social incentive to replace them with a more stylish or feature-filled newer model every eighteen months. There would also be fewer phones per American – many families could do with one or two instead of one for each family member.

However, this is not a realistic model. Americans have already proven that they favor cordless phones over corded, and that they are willing to replace landlines entirely with cell phones in large numbers. It would seem inevitable that the same process we see occurring today in the real U.S. would result in the eventual replacement of millions landlines with cells. As consumers purchased more and more cell phones, cell towers would have to be built, and the existing landline network would quickly become redundant and obsolete. At the same time, Americans would be purchasing energy-sucking cordless phones for their land lines as well. Unless the government decided to make cell phones and cordless phones illegal – a rather draconian measure – we would soon be in the same fix we are in now, with millions of watt-draining cordless phones *and* cell phones. It would be better for the country, energetically, if everyone just used cell phones instead of just using 2/3rds cordless and 1/3 corded landlines. For these reasons, it would be better to simply build a cell network in the first place, to avoid building two nationwide communication networks that cover the same areas.

If the additional side benefits of cell phones are considered, this option becomes even more attractive. Cell phones provide a sense of safety – parents don't have to worry so much about their children being stranded without a way to call home, travelers whose cars break down can call for assistance, and citizens can call emergency services more quickly in the event of a fire, assault, robbery, or other catastrophe. Cell phones also have caused a revolution in the way business is carried out – the greater speed and efficiency of business communication on mobile phones leads to increased profits and a stronger economy. Socially, it's also difficult to see a country of America's wealth and technical sophistication getting by without cells. In only a few decades, cell phones have become status symbols, entertainment devices, and even companions, in a sense.

However, there are a few weaknesses to an all-cell network. Businesses would have to issue employees cell phones to replace their desk phones (many employees would not want to use their personal cell phones, because it would allow any business contact to invade their privacy at any time), and it would be difficult to prevent them from using their minutes for personal calls. Families would no longer have a dedicated landline in the house that was reliable, always on, and inexpensive. And cells do have a few major security and safety concerns. Of course, there is the current debate about whether or not cell phones could cause cancer. There are plenty of sources arguing on either side of the debate, but we don't feel that there is enough information or time to draw even tentative conclusions. Still, it is clear that some would prefer to have a non-cell alternative to at least limit their exposure. On the security side of things, it is well established that cell phones can be vulnerable to hackers, interception, and jamming. The government and many corporations would probably not want to rely solely on cells for this reason, so a few landlines might have to be installed for them. On the other side of things, having every American citizen talking on a cell phone would allow the government to listen in on any calls it liked, without the physical evidence of a wiretap. Protectors of civil rights would no doubt be alarmed by this development.

Luckily, there is a simple, cheap, and energetically conservative way to solve several of these problems: VOIP. Assuming that this country had about the same technology level as the U.S., an extensive network of internet cables would already be in place, snaking in between all but the smallest towns, and connecting to around 37% of households across the country (the 24% of houses that would have been on dial-up would not be connected, as there would be no phone lines)[25]. Attaching the remaining 63% of homes to the existing DSL and cable hubs already scattered through neighborhoods across the country would be considerably easier than laying new phone lines underground, throwing up millions of phone poles, or constructing thousands of cell towers. The technology to send voice data over the Internet has already been mastered – in the fourth quarter of 2008, Skype reported 405 million accounts worldwide[26]. Even those homes without a computer could be served by a phone that plugs directly into an internet router. This technology would likely be simple to develop, considering the existing similarity between a phone jack and an internet jack – it just does not exist today because there is no need to develop it with a landline system already in place in the real United States. Modern internet cables can transmit such a large volume of information that the additional auditory data would be fairly trivial. VOIP would also use a very small amount of resources, relative to a full cell or landline network. Cordless VOIP phones might consume a fair bit of power, but the savings on construction and infrastructure costs would be enormous – the majority of the internet cable that would be required would already have been laid. In combination with a full cell network, VOIP would allow business to give their employees a phone which they could be held accountable for, but which would also preserve the employee's privacy. Families could have a backup VOIP line which would be comfortable to talk on for long conversations. And thanks to the cell network, Americans could communicate while traveling or living anywhere in the country.

Along with the implementation of this system would come a mandatory cell phone recycling program. Much of the energy cost of production of new cell phones could be alleviated by simply recycling old cell phones. Specifically, if the Pseudo US were to recycle 100 million cell phones, this would save enough energy to power 19,500 households for a year[27]. This equates to 0.215 TWh.

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[25] Table HC2.11, Energy Information Association.

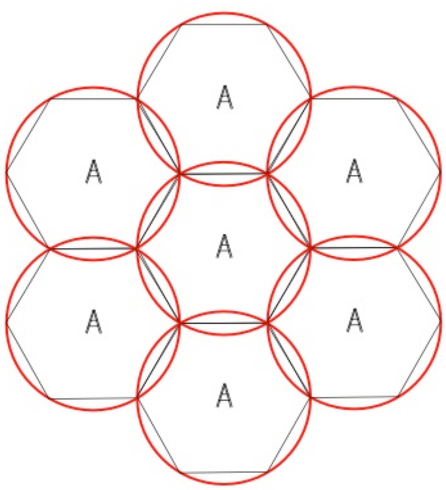
[26] "Skype Fast Facts Q4 2008."

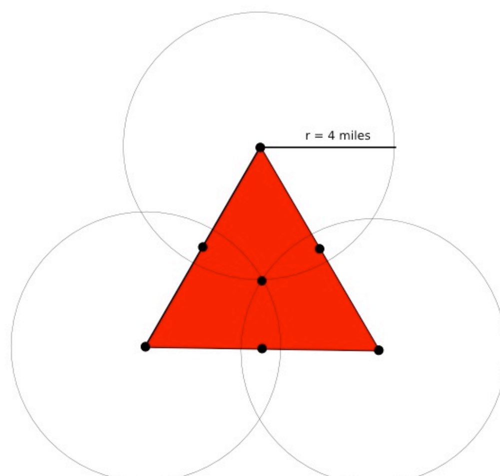
[27] "Recycle Your Cell Phone. It's an Easy Call," Environmental Protection Agency.

-Covering the Pseudo US with Cell Towers

With our implementation of an all-cell phone system, our primary obstacle is the construction of cell towers. In our research, we have found several different types of cell towers, but since we are looking for the most energy efficient way to implement this system and we have the advantage of starting from scratch, the obvious choice seems to be the newly released Ericsson Tower Tube cell tower. It has a radial range of approximately 4 miles and has a wind turbine attached, so it uses 40% less energy than conventional towers. A modular design allows it to be erected in a matter of days (the foundation can be complete in eight hours), it has a small footprint of 19.6 square meters, it's resistant to vandalism and the elements due to an enclosed design, and it uses heat convection cooling to further reduce its energy cost[28]. It also has a shape aesthetically pleasing enough that it shouldn't drive down property costs unduly, especially since its concrete structure can be formed in a variety of colors, shapes, and heights. Also, if this type of tower is used exclusively, the relative cost, both monetarily and energetically, would be less than trying to manufacture several different types of towers and implant them into the same areas simultaneously.

Now, it becomes our goal to cover the Pseudo US in the most efficient way possible. Knowing nothing about the geography of the pseudo nation, we will devise the optimal grid for cell tower placement based upon data from the current United States. We want to minimize the number of towers in the nation while maximizing coverage. Using some basic geometry, the most efficient way to obtain 100% coverage of the nation is through a triangular lattice, as seen below, with each tower the vertex of an equilateral triangle, and 6.93 miles from each other tower (determined with simple trigonometry). This does assume a perfect scenario, as signal strength falls off with distance, and in reality towers would be placed closer to ensure coverage at the intersection points.





This lattice assures minimal wasted coverage; the circles' overlap is minimized. If we were to place this tiling of throughout the current United States, since each cell tower encompasses a unique hexagonal area of 41.57 mi^2 and the land area of the US is approximately 3,540,000 mi^2, we would need approximately 85,150 towers.

[28] "Ericcson Tower Tube," Ericcson.

Naturally, this sort of cell tower arrangement cannot and should not be implemented everywhere. For cities, we have devised a system that gives an estimate of the necessary density of the cell tower population based upon the population of the city. Each cell tower has a limitation on the number of users it can support, so obviously additional towers must be introduced into most cities over the size of 10,000.

Even though we are talking about a Pseudo US, the most tangible data concerns the real United States. According to the 2000 Census, there are currently 601 US cities over the size of 50,000 people. We analyzed the population densities of each of these cities and determined that in general, the density of cell towers in these metropolitan areas should be around 16 times the average density of the rest of our grid. This adds approximately 420 cell towers to our previously calculated total. Since there is no data on the remaining cities under 50,000 people, we recommend that for all cities between 10,000-50,000, the density of cell towers be increased by 4 times to meet the cell phone service needs. Information on the possible cost or energy consumption of this network is difficult to come by – modern telecommunication companies didn't get where they are today by giving out important data about their operations. The best estimate we can make involves the Ericsson's Tower Tube's 10kW of signal strength. As our network would use 85,570 towers, this would mean energy consumption would be at least 0.312 TWh for the tower's themselves – a surprisingly low amount, but cooling, manufacture, and other operational costs would likely drive it up considerably.

-**Wasted Electricity Due to Cell Phone Rechargers in Pseudo US**

Energy wasted by cell phone rechargers in this pseudo U.S. can be determined using the same calculations used to calculated recharger waste in the real U.S. We will simply discard the older phones with the more wasteful rechargers, and assume that every cell phone using American will have one of the new chargers that only wastes 0.2 W on standby power while left plugged in alone, and 0.4 while plugged in to a fully charged phone. As before, the top shows the average number of hours a pseudo American leaves their phone plugged in after it has reached full charge, and the left side shows the average number of time they recharge their phone in a year.

	2 hours	4.5 hours	6 hours
100 recharges	0.359 TWh		0.386 TWh
175 recharges		0.398 TWh	
365 recharges	0.395 TWh		0.494 TWh

From our simulations, our pseudo U.S. would waste 30% less energy due to cell phone rechargers than the real U.S, even if the pseudo Americans left their phone plugged in just as long as we do. The 0.398 TWh estimate would equal 234,118 barrels of oil. This is an encouraging fact, as the real United States will basically reach this state in a few years, as more and more older cell phones are replaced. As before, we ran a second simulation to see what would happen if all pseudo American unplugged their chargers and phones at the same time.

	2 hours	4.5 hours	6 hours
100 recharges	0.022 TWh		0.065 TWh
175 recharges		0.086 TWh	
365 recharges	0.079 TWh		0.238 TWh

If the pseudo Americans could unplug both phones and chargers, refrain from recharging their cells until absolutely necessary, and unplug them within two hours of them reaching full charge, they could basically make standby power waste from cell phones disappear entirely (only 0.022 TWh/year, or 1.71% of our current estimated waste). That would still be 12,941 barrels of oil wasted annually, but it would be a vast improvement.

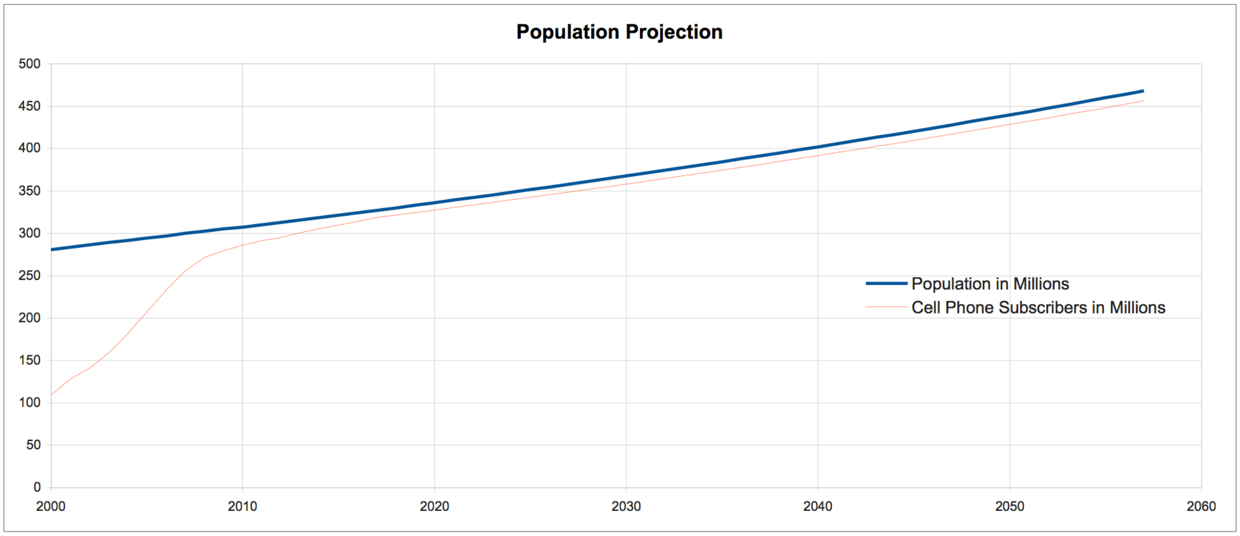
SECTION 4: Increase in Phone Energy Needs for the Pseudo US

Now that we have created a communication environment for the Pseudo US, we would like to model the electricity needs for the phone system over the next 50 years. This model will depend heavily on both population growth and economic growth. We have established reasonable trends for each and described why the population data is more significant than the specific economic data.

-Population Growth

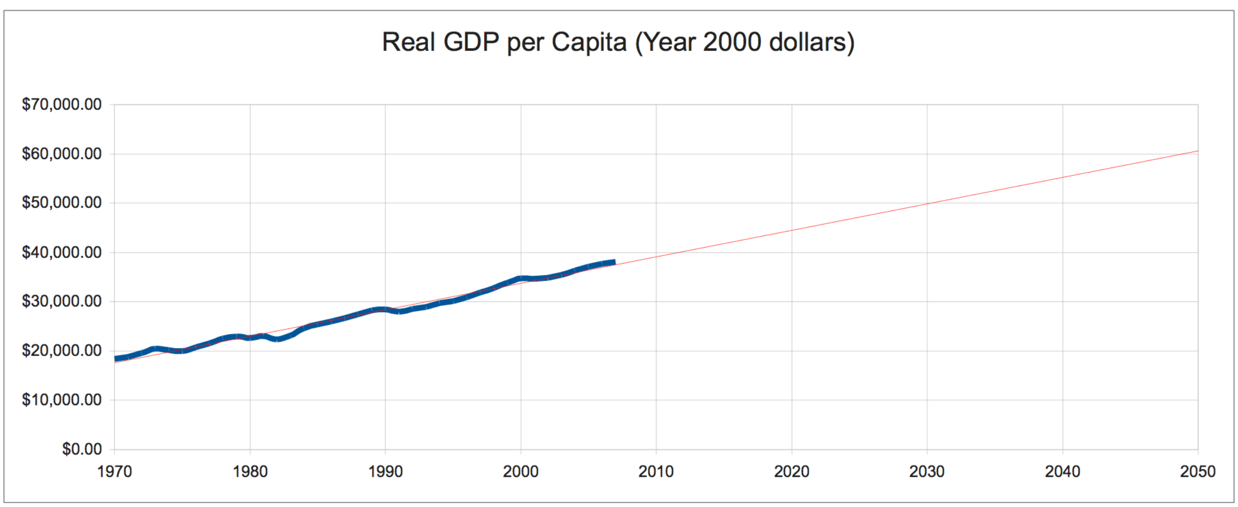
Starting with population growth, we have found that the growth rate will be approximately 0.9% increase annually. The graph below represents our prediction of the population growth based upon the growth trend of the United States over the past several years. The CIA World Factbook has corroborated our prediction[29]. With our projection system, we will obtain maximum cell phone usage (97.5%) by the year 2015. We suspect that there will always remain a small number of holdouts – infants, those who eschew technology in general, or those who believe cell phones cause cancer. Our model, based on population growth, is helped by the fact that cell phones are not like T.V. sets or jeans – even if they become even more popular than they currently are, or if there is some huge economic boom in the next fifty years, it seems unlikely that the average American would buy three, four, or eight cell phones – the ratio will likely remain close to 1:1 (at least in terms of the phones that are actually used, and thus consuming energy). So we predict that the number of cell phone subscribers will run parallel to, but just below the number of Americans.

[29] "United States," CIA World Factbook.



-Economic Growth

It's an understatement to say that the economic growth of the United States over the next 50 years is difficult to predict. When we simply plotted the real GDP per capita of the country, however, we found that there was a surprisingly robust trend[30].



The economic depression of the 1980s is clearly visible on this chart, yet there is still a strong upward trend in GDP. Even with the current economic instability, this data suggests there is a good chance that in the long term, over the next 50 years, the U.S. economy will continue to grow at approximately the same rate it has been growing for the last four decades. This should be enough to allow almost all Americans to own a cell phone. We also predict that demand will remain high. Mobile phones have become such an integral part of American life, like the

[30] "US Real GDP Per Capita," Measuringworth.org.

television, that nearly all Americans will own one whether the economy is in recession or in boom.

-Discussion of Technological Advancement

A cell phone network, combined with VOIP technology, would also have an advantage over a landline network in that it would be more easily expanded and upgraded over the next 50 years. Unlike landlines, which have for the most part reached their potential, cell and VOIP technology still have room for improvements in broadcast distance, bandwidth, voice quality, energy efficiency, and cost reduction. Landlines would have to be extended through trenches or on poles to any new houses built in the U.S., while the existing cell network described in Section 3 would be able to handle new customers in any part of the country. Perhaps a few more towers would have to be built to account for the increased signal load, but geographically the entire country is already covered. The existing cell towers could be upgraded at any time with more powerful transmitters, solar panels for increased energy efficiency, or any other technological advances that might come about in the next five decades. And if we connected these towers with high-bandwidth, advanced fiber optic cables when they were first constructed, there would be room for the subscriber base to grow. This could also lead to powerful mixed technologies, such as wireless Internet transmitters mounted on the cell towers, blanketing large sections of the country with wi-fi coverage. If wireless technology is improved, this might eventually allow Americans to choose to communicate using the cell network, VOIP, instant messaging, email, or web-cams from anywhere in the country. A landline network could not provide this level of expansibility and upgradeability for decades to come.

One of the most exciting ways to upgrade would be adding a satellite network. If incremental improvements in satellite communications could be made, satellites could be an extremely attractive choice for covering the Rocky Mountain states and parts of the Midwest. We compiled a list of 15 contiguous states and Alaska, from Oregon to Kansas to New Mexico. This list contains fourteen of the fifteen most sparsely populated states, excluding Maine and also includes Arizona. Together, these states contain 52% of the area of the United States but only 12% of its population[31], and as they are contiguous, they would be the easiest to cover efficiently with satellites. If this network could be made operational immediately in 2008, we could simply not build any of the 44,278 cell towers that would have been in that area, a huge amount of savings in materials, energy, labor, and money. Unfortunately, there would likely be too many complex technological problems to overcome at that time. First, though satellite phones can currently text cell phones, modern cell phones do not have nearly enough power to reach satellites. Secondly, current satellite phones have problems getting calls in doors or in mountainous areas due to line of sight problems. Finally, some satellite phones have a noticeable lag in their conversations.

Using low Earth orbit satellites would limit the lag time in conversations and reduce line of sight problems (these satellites orbit the Earth at an incredible speed, making a complete rotation in about an hour and a half, so one will be in line of sight of almost any location shortly[32]). But using orbiting satellites instead of geostationary ones would mean the satellites would be over the U.S. only a fraction of the time – to be fully efficient, this satellite system would have to be international. There would also need to be an improvement to signal strength,

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[31]"U.S. state," (state lists lower on the page), Wikipedia.
[32] "Satellite Phone," Wikipedia.

both to improve performance, and to reduce the power the phone itself would have to burn through to transmit receive a signal, before satellite phones would really be ready to be used by millions. Satellites have the further downside of not being able to deal with the same call load as a cell network or a landline network, though this would be somewhat mitigated by the fact that the satellites would only be handling the sparsely populated areas. All in all, it would appear that attempting to create a hybrid sat/cell phone in 2008 would only result in a hideously expensive, complex, bulky piece of equipment. But if the technology has been improved by the time the first generation of cell towers are due for replacement anyways, it might be worth replacing 44,000 or so cell towers in the Rocky Mountain and Midwest areas with a handful of satellites.

-Prediction of Energy Needs Over the Next 50 Years

Taking these predictions of population and economic growth over the next 50 years together with an assumed increase in the energy efficiency of cell phone technology, we have created the following energy costs due to consumer use. For the first model, we will assume that cell phone efficiency remains constant throughout the next 50 years. That is, phones will continue to require the same amount of energy to charge, throughout the entire time period. Essentially there is no technological advancement in terms of energy efficiency.

For the second model, we will take into account the technological advancements concerning cell phone and their rechargers, as well as a transition toward other telecommunication options referenced above. We anticipate that standby power waste would be nearly eliminated, if improvements in this field continue as they have for the past few years. Batteries would take longer to run out, and phones would need to be recharged less often, as cell technology became more advanced. For this second type of value, we will incorporate an exponential decay constant, lambda, which accounts for a lambda percent decrease in energy used to power each cell phone each year. Our equation will be:

$$Energy(t) = .922 * (1.009)^t * (1-\lambda)^t$$

If we use these two models for the next 50 years, and use a value of .02 for lambda, we obtain the following data. The values in each box below are in terms of barrels of oil for the given period only, and account for consumer usage, not production costs or cell tower and satellite construction.

	2009	2019	2029	2039	2049	2059
All Cells – Holding Energy Efficiency Constant	.922	1.07	1.17	1.28	1.40	1.53
All Cells – Incorporting Technological Advancements	.922	.824	.736	.658	.588	.525

*In million barrels of oil

SECTION 5: Energy Wasted by Consumer Electronics

If cell phone chargers could waste over a terawatt hour of electricity in a year, how much energy might be leaking out of other chargers and plugs in the modern American household? Many devices, specifically, are known to draw standby power even while off – any device with a remote certainly does this, and others leak electricity as well, simply because manufacturers were too cheap to supply plugs and chargers that shut off fully when a device is turned off. Theoretically, any appliance with a plug, such as a lamp, is going to leak a small amount of power. However, we found that there was just not enough reliable data on the number and usage of light fixtures to study lighting. We were able to study the energy consumption of the other main group of plug-bearing devices, consumer electronics, using a variety of sources. The Energy Information Administration of the Department of Energy produced a lengthy study on the types of appliances and electronics in American homes[33]. Many other sources detailed wattages and average kWh/year consumed by various devices – a writer for the Wall Street Journal who had purchased a power meter, electric companies, a group of Canadian scientists, and the City of Seattle, among others[34]. But a report by TIAX LCC., commissioned by the Consumer Electronics Association, was by far the most thorough, combining data on electronics wattages and usage patterns into a comprehensive study[35]. The data was gathered together from their own studies, previous EIA and CEA studies, and information from electronics suppliers, scholarly articles, and Energy Star testing. The only major consumer electronics they did not report on were digital TVs, and they could also only provide yearly consumption estimates for component stereos, printers, and modems. We checked all of their wattage and usage data using the sources mentioned above, and filled in the gaps with corroborated data and best-guess estimates on wattages and usage from a variety of sources cited in the individual sections below. We also updated the study (completed in January of 2007) as best we could, especially when considering VCRs and game consoles, whose use has changed drastically in the last two years. A summary of data is presented below, by type in order of total consumption. Note that some devices, like TVs or modems, do not have an idle state – they either run at full power or are turned off. Also, the numbers in these tables are total TWh consumed by all of the electronic devices of that type in the country in a year – relative amounts of each device are taken into account.

Analog TVs: The TIAX report was very thorough on this subject, utilizing data on TV usage even down to the sixth-most used TV in a house. As such, there was little we could do to improve on it, save to say that the historical increase in analog TV usage has probably begun to level off in the past two years due to the increasing popularity of digital TVs.

Active	Idle	Off	Total
43.6 TWh	n/a	6.4 TWh	50.0 TWh

[33] "Table US-1. Electricity Consumption by End Use in U.S. Households, 2001," Energy Information Association.
[34] City of Ames, ABS Alaskan, City of Seattle, the Wall Street Journal, Dot-Com Alliance, David MacKay, afterdawn.com, and Fung et. Al.
[35] Roth and McKenney, TIAX LLC.

Analog TVs appear to be fairly wasteful, due to the average of 4 Ws they leak while turned off. This does not even take into account the power they waste while turned on with no one watching them.

Digital TVs: Estimating the TWh used and wasted by digital TVs proved difficult. It quickly became clear that there was a huge variation in wattages, from 100 W up to 400 or 500 W. A massive chart provided by CNET.com showed that the average wattage of new HDTVs averages out to be around 250 W, and that standby power on most new digital TVs has been reduced to about 1 watt[36]. This data was supported by wattage information on TVs from the other comprehensive appliance wattage lists cited above. For usage data, we assumed that in most cases the digital TV, being the newest TV, would be the television most-used in the household, so we used the usage data TIAX had gathered for the most-used TV. We then found that about 19.25 million flat-screen TVs had been sold since the study was done, meaning that there were now 59.25 million digital TVs in the country[37]. This data allowed us to estimate the power consumption of digital televisions as follows:

Active	Idle	Off	Total
37.8 TWh	n/a	0.36 TWh	38.2 TWh

Digital TVs actually provide a bright spot in this study of waste. They do use a huge amount of power when on, but at least their standby power has been minimized. They waste less than a percent of the total energy put into them, while analog TVs waste over 12 %. From our research, it appeared that the Energy Star program was at least partially responsible for this limitation. Unfortunately, electronics manufacturers have no inherent pressure on them to limit standby power, as its cheaper for them to make wasteful, leaky plugs, and the cost of the lost energy is stealthily passed on to the consumer. Programs like Energy Star make this hidden cost of electronics ownership more visible to the public, and reward manufacturers for bringing down their standby power by advertising their efficiency for them.

Desktop computers: Again, the report to the CEA was incredibly complete on the subject of desktop computers: analyzing CRT and LCD monitors separately, then combining them into a weighted total, averaging out the wattages of many different types of desktops, and recording and taking into account the amounts of time spent in screensaver and standby modes.

Active	Idle	Off	Total
20.2 TWh	0.09	0.99 TWh	21.2 TWh

Set-top boxes (Cable, satellite, and other TV boxes): Results on this electronics type were very interesting. Total consumption was fourth out of all electronics types, but over a third of that consumption was used while the box was not being used to watch TV. By TWh, set-top boxes waste more energy than any other type of electronics device that we studied – a surprising fact, as there area almost a million fewer set-top boxes than analog TVs. The boxes still use 15 W when off, presumably so that they can stay in contact with the service provider, and in some

[36] CNET.com.

[37] Chris Burritt, Bloomberg.com

cases perform services like turning on at a certain time to record a show. If these boxes could be made more efficient when off, a vast amount of electricity could be saved.

Active	Idle	Off	Total
6.36 TWh	n/a	13.3 TWh	19.7 TWh

Compact audio: Compact audio systems had one of the widest variations in wattages between devices, so the TIAX study was invaluable in weighting these different wattages against the various numbers of these systems in use. Clearly, this is another area for improvement, with significant waste arising in both the idle and off stages.

Active	Idle	Off	Total
1.44 TWh	0.912 TWh	3.8 TWh	6.16 TWh

Component Stereo: TIAX only estimated that a component stereo might use 115 kWh per year, and claimed they had an installed base of 50 million units. To fill in the gaps, we figured that the stereo would have a usage pattern similar to a compact audio system, with wattage more like a home theater in a box. By using reasonable numbers for wattage and usage, we calculated a stereo would use about 105.17 kWh a year.

Active	Idle	Off	Total
1.47 TWh	0.913	2.88 TWh	5.26 TWh

Game consoles: This was one area where the TIAX report's age became an issue. They reported only 2.624 TWh used by game consoles, with 0.96 TWh going to their active state, 1.28 used while idle, and 0.384 consumed while off. But game consoles have not only become more popular since January 2007, but the proportion of older generation consoles to new consoles has also gone down. This becomes important because the newer, more advanced consoles are considerably more power hungry. TIAX reported an average wattage of 36 W for consoles, but multiple sources we found cited the new Xbox 360's wattage around 173 W and the Playstation 3's at about 190 W. Nintendo's Wii apparently has a much lower wattage, at about 18 or 19 W, but the average wattage of consoles should still be significantly higher than 36 W.

Also, TIAX reported 64 million consoles in the U.S, but since then Wiis in the U.S. have jumped from 1.5 million to 13.5 million, Xbox 360s have gone from 4.8 million to 11.9 million, and PS3s have increased from 0.8 million to 5.9 million [38]. With the influx of these 24 million new game consoles, we estimated that 12 million of the older game consoles would be removed from use (TIAX reported that there were 64 million in January 2007). So, there are now about 52 million older game consoles averaging around 36 W, plus 12 million new Wiis using 19 W, 7 million new Xboxes consuming 173 W, and 5 million new PS3s drawing 190 W. By weighting these numbers and wattages, we found that the new average wattage is likely closer to 56 W.

Active	Idle	Off	Total
1.72 TWh	2.38 TWh	0.711 TWh	4.82 TWh

[38] James Brightman, GameDaily.

Game consoles and home theater systems had a similar problem – they both use about the same amount of power when in use or when just sitting idle. This results in a high amount of power being wasted while these electronics are left on before, after, and in between uses.

DVD players: Another problem area, DVD players wasted a staggering 87% of the energy they used, the second most by percentage of any device we studied. This has probably only increased in recent years as consumers have purchased HD-DVD and Blu-Ray players as well.

Active	Idle	Off	Total
0.54 TWh	1.15 TWh	2.64 TWh	4.33 TWh

VCRs: This was another area where we felt we had to correct for the two years between the TIAX study and the present day. They cited a total of 4.9875 TWh used by VCRs, even more than DVDs. A breakdown does show that the vast majority of this power was used while idle (1.05 TWh) or off (3.675 TWh), which is what one would expect for a dying technology, but the number of VCRs in use has also dropped since the study was performed. Data from previous studies they cited indicates that the number of VCRs has decreased by an about 11.25% a year from 2001 to 2005. We extended this trend to the end of 2008 for an estimate of 71 million VCRs operational in the U.S. today. We also adjusted their usage numbers downwards by about 15% to account for more families preferring to use their new DVD player over their VCR, resulting in the following data:

Active	Idle	Off	Total
0.151 TWh	0.574 TWh	2.54 TWh	3.27 TWh

VCRs turned out to be the energy-wasting champion by percentage, wasting over 95% of the energy that they consume. A great deal of electricity could be conserved if Americans would unplug their VCR during the long stretches they don’t use it.

Laptop computers: Surprisingly efficient, laptops used over seven times less electricity than desktop computers even though there are only twice as many desktops. However, this is apparently due to the fact that they only use 25 W while active instead of the 75 that desktops use, because they wasted 18% of their energy compared to only 5% wasted by desktops.

Active	Idle	Off	Total
2.3 TWh	0.078 TWh	0.429 TWh	2.81 TWh

Modems: Another interesting case, because they are basically left on all the time, yet thankfully have a fairly low wattage (about 7 W, we found[39]). Using these estimates, we found they might use 54.75 kWh a year, higher than TIAX’s estimate of 53, but close.

Active	Idle	Off	Total
0.705 TWh	n/a	1.81 TWh	2.52 TWh

[39] “Sustainable Energy – without the hot air,” David MacKay.

Assuming modems are used 6 hours a day (about 25% less than computers, which we felt accounted for the many computers not attached to cable or DSL modems while still accounting for family modems that might be connected almost all day), this means that only 0.705 TWh a year are being used by modems while people are actually connected to the internet. The other 1.812 TWh lost as waste could be saved if people would unplug their modems when they were not in use.

Home Theater in a Box: This was one of the most efficient devices when off, despite its size. This is probably due to the fact that like digital TVs, many home theater systems are fairly new, and thus affected by Energy Star standby power guidelines. If Americans could learn to turn their home theaters off when not in use more regularly, the waste of these electronics would be quite minimal.

Active	Idle	Off	Total
1.5 TWh	0.625 TWh	0.1 TWh	2.23 TWh

Printers: Printers were an interesting case, as they can suck vast amounts of energy while in use, but in most households would be actually printing for only a few minutes a day, on average. Unfortunately, their idling wattage also appears to be quite high, and the proportion of printers left on at all times is probably also substantial. We found wattage information varied considerably, but a reasonable average is 300 W while active and 12 W while on[40]. Along with the assumption that an average household printer is used 5 minutes a day and on 4 hours a day, we feel that a printer might use 33.79 kWh a year, close to TIAX's estimate of 30.

Active	Idle	Off	Total
0.27 TWh	0.526 TWh	0.218 TWh	1.01 TWh

Overall, a breakdown by device type reveals that it is actually the TV complex, not the computer complex, which is responsible for the majority of this waste. Together, DVD players, VCRs, TVs, game consoles, set-top boxes, and home theaters accounted for 4.73 TWh of the idling waste and 26.1 TWh of the electricity lost while devices are turned off. Monitors, printers, desktop computers, and modems, on the other hand, only counted for 0.706 TWh of idling waste and 3.47 TWh of off waste. If the TV and its related devices were all plugged in to a power strip which was turned off when the electronics were not in use, American households would use 18% less energy on electronics (though one should be careful to turn off the TV before the power strip, as a sudden loss of power can damage a television set). As the average American household uses 11% of its energy on household electronics[41], this would represent a 2% reduction in overall residential electricity usage. Power strips could even be fitted with a remote control power switch – they would consume a slight amount of standby power as they sat waiting for the remote signal, but the devices plugged in to them would not. This would actually be a *more* convenient way to turn off electronics that would also save valuable electricity.

[40] "ICT Power Consumption Reference Tables," Dot-Com Alliance.
[41] Roth and McKenney, TIAX LLC.

In all, we found that this selection of household electronics might consume around 169 TWh of electricity a year in the U.S, or approximately 99,411,765 barrels of oil, considerably more than the 1.281 TWh/year we estimated cell phone chargers waste. 125 TWh of this total would be used while the devices were actually in use, 7.34 TWh would be wasted as they sat on but idle, and 36.7 TWh would be lost as leakage even while they were off but still plugged in. By percentage, 26% of a house's energy spent on electronics is wasted: 21,588,235 barrels of oil wasted by standby power and 4,317,647 barrels wasted by electronics left on but sitting idle. For confirmation, David MacKay attempted to minimize his standby power waste by unplugging everything he could, and found that he could save 1.1 kWh per day[42]. Our data, when totaled, suggests that the average American could save 1.03 kWh per day (376 kWh per year) by doing the same.

[42] "Sustainable Energy – without the hot air," David MacKay.

Citations

Bavdek, Maureen. “Nearly 1 in 5 U.S. Households Have No Phone.” 17 Dec 2008. Reuters. 7 Feb 2008 <http://www.pcmag.com/article2/0,2817,2337125,00.asp>.

Brightman, James. “Wii U.S. Installed Base Now Leads Xbox 360 by Almost 2 Million.” 14 Nov 2008. GameDaily. 8 Feb 2009 <http://www.gamedaily.com/articles/news/wii-us-installed-base-now-leads-xbox-360-by-almost-2-million>.

Burritt, Chris. “Super Bowl May Spur Fewer TV Sales as Retailers Fight Slump.” 30 Jan 2009. Bloomberg . 8 Feb 2009 <(http://www.bloomberg.com/apps/news?pid=20601103&sid=a4OnWOI6j7.c&refer=news>.

“Call My Cell: Wireless Substitution in the United States.” Sep 2008. The Nielsen Company. 7 Feb 2009 <http://www.nielsenmobile.com/documents/WirelessSubstitution.pdf>.

“Cell Phone Recycling Facts.” 9 Aug 2008. Recycling for Charities. 8 Feb 2009 <http://www.recyclingforcharities.com/blog/?p=9>.

“Cell Phone Subscribers in the U.S., 1985-2005.” Infoplease. 7 Feb 2009 <http://www.infoplease.com/ipa/A0933563.html>.

“Cell Phones and Devices.” AT&T. 6 Feb 2009 <http://www.wireless.att.com/cell-phone service/cell-phones/index.jsp>.

“Charger Energy Efficiency.” Motorola. 8 Feb 2009. <http://www.motorola.com/content.jsp?globalObjectId=9392>.

“Common Household Appliance Energy Use.” Ames City Government. 6 Feb 2009 <http://www.cityofames.org/electricweb/Energyguy/appliances.htm>.

Dixon, Kim. “U.S. cell-only households keep climbing.” 17 Dec 2008. Reuters. 7 Feb 2009 <http://www.reuters.com/article/technologyNews/idUSTRE4BG5GH20081217>.

“Electricity Basic Statistics.” Jan 2009. Energy Information Association. 9 Feb 2009 < http://www.eia.doe.gov/basics/quickelectric.html>.

“Ericsson Tower Tube.” Ericsson. 9 Feb 2009 <http://www.ericsson.com/campaign/towertube/>.

“Estimated Current US Wireless Subscribers.” CTIA The Wireless Association. 6 Feb 2009 <http://ctia.org/>.

Etoh, Minoru. “A Power Consumption Ratio, 1:150.” 23 March 2008. A Wandering Engineer’s Remarks. 7 Feb 2009 <http://micketoh.blogspot.com/2008/03/power-consumption-ratio1150.html>.

Fry, Jason. “A Hunt for Energy Hogs.” 18 Dec 2006. The Wall Street Journal. 6 Feb 2009 <http://online.wsj.com/public/article/SB116603460189049162-04zk0DLUxdchdcCNfF4I_Q8jDZU_20071218.html?mod=blogs>.

Fung, Alan S. Adam Aulenback, Alex Ferguson, and V. Ismet Ugursal. “Standby power requirements of household appliances in Canada.” 24 May 2002. Energy and Buildings, Volume 35, Issue 2. 7 Feb 2007 <http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V2V-45X2RF8-D&_user=6046335&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000069202&_version=1&_urlVersion=0&_userid=6046335&md5=1c63a4b640ba73c78ed66a358c89df32>.

“ICT Power Consumption Reference Tables.” Dot-Com Alliance. 7 Feb 2009. <http://www.dot-com-alliance.org/POWERING_ICT/Text/hotwords/Data_on_Power_Consumption.html#Table6>.

MacKay, David. “Sustainable Energy – without the hot air.” 2009. 7 Feb 2009 <http://www.inference.phy.cam.ac.uk/sustainable/book/tex/sewtha.pdf>.
“Population Clocks.” U.S. Census Bureau. 6 Feb 2009 <http://www.census.gov/>.
“Power consumption of common home electronics devices.” 19 Nov 2007. Afterdawn.com. 6 Feb 2009 <http://my.afterdawn.com/ketola/blog_entry.cfm/2423/ home_electronics_power_consumption>.
“Power Consumption Table.” ABS Alaskan. 6 Feb 2009 <http://www.absak.com/library/powerconsumption-table>.
“Recycle Your Cell Phone. It’s an Easy Call.” EPA. 7 Feb 2009 <http://www.epa.gov/epawaste/partnerships/plugin/cellphone/index.htm>
Richard, Micheal Graham. “Treehugger Homework: Unplug Your Cellphone Charger.” 26 Nov 2005. Treehugger. 6 Feb 2009 <http://www.treehugger.com/files/2005/11/treehugger_home_2.php>.
Roth, Kurt W., and Kurtis McKenney. “Energy Consumption by Consumer Electronics in U.S. Residences.” Jan 2007. TIAX LLC. 6 Feb 2009 <http://www.ce.org/pdf/Energy%20Consumption%20by%20CE%20in%20U.S.%20Residences%20(January%202007).pdf >.
“Skype Fast Facts Q4 2008.” Skype. 8 Feb 2009 <http://ebayinkblog.com/wp content/uploads/2009/01/skype-fast-facts-q4-08.pdf>.
Stover, Dawn. “Cell phone recycling for cash a win-win, or is it?” 23 Jan 2008. MSNBC. 8 Feb 2009 <http://www.msnbc.msn.com/id/22671798/>.
“Stretch your energy dollar.” Seattle City Light. 6 Feb 2009 <http://www.ci.seattle.wa.us/ light/accounts/stretchyourdollar/ac5_appl.htm#Entertainment>.
“Sustainable energy use in mobile communications.” Aug 2007. Ericcson. 6 Feb 2009 < http://www.ericsson.com/technology/whitepapers/sustainable_energy.pdf>.
“Table HC2.11 Home Electronics Characteristics by Type of Housing Unit, 2005.” Energy Information Administration 7 Feb 2009 <http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc11homeelectronics/pdf/alltables.pdf>.
“Table US-1. Electricity Consumption by End Use in U.S. Households, 2001.” Energy Information Administration. 6 Feb 2009 < http://www.eia.doe.gov/emeu/recs/recs2001/enduse2001/enduse2001.html>.
“The chart: 139 HDTV’s power consumption compared.” CNET. 7 Feb 2009 <http://reviews.cnet.com/4520-6475_7-6400401-3.html?tag=rb_content;rb_mtx>.
“United States.” 5 Feb 2009. CIA World Factbook. 9 Feb 2009 <https://www.cia.gov/library/publications/the-world-factbook/print/us.html>.
“US Real GDP Per Capita.” Measuring Worth. 7 Feb 2009 <http://www.measuringworth.org/datasets/usgdp/graph.php>.
“U.S. State.” 4 Feb 2009. Wikipedia. 8 Feb 2009 <http://en.wikipedia.org/wiki/U.S._states>.
Virki, Tarmo. “Cellphone industry eyes charger power savings.” 19 Nov 2008. Reuters. 8 Feb 2009 < http://www.reuters.com/article/technologyNews/idUSTRE4AI2T520081119>.
“Wireless Recycling Frequently Asked Questions.” ReCellular. 8 Feb 2009 <http://www.recellular.com/recycling/faqs.asp>.
“Zero power consumption from battery chargers when not in use.” IP.com. 6 Feb 2009 <http://www.priorartdatabase.com/IPCOM/000146735/>.