Here Comes the Sun … or is it the Wind?

New Mexico

Supercomputing Challenge Final Report

Team #36

Edgewood Elementary

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Executive Summary

The “Here Comes the Sun…. or is it the Wind?” project is about wind and solar energy and which will cost less and output more energy for Edgewood, New Mexico. Our team decided to do this project because wind and solar energy are both clean and renewable. Then we thought it would be a great idea to see how they would work in Edgewood (our home town) and which one would work the best. Our hypothesis was that solar would output more energy at a lower cost.

We at first thought we should compare solar or wind with coal and oil but we knew what the outcome would be; wind or solar would cost more but have less CO_2 emissions. So when we decided on our purpose, we went to work. We researched everything from websites to periodicals to learn about solar and wind. We went on field trips to the New Mexico Wind Energy Center near Ft. Sumner and met with an expert solar scientist from Sandia Labs, Greg Nielson. We researched electrical usage in our state and community. We graphed electrical usage from our electric bills. To make our model, we specifically researched Edgewood weather. We thought this was so important. Without this information, our model could have been based off of Chicago or New York, which is why we spent many months on careful research.

Once we did that we put our Starlogo TNG models together. Our models track power output across the calendar year based on our monthly average weather conditions so we could determine how many kWh our panels and turbines would output. We spent hard hours putting randomness and research into our model. Finally, the models were done. We ran our model through six years to get our results. The wind came out to cost approximately $18,000,000 and $2.05 per kWh and solar costs approximately $16,000,000 and $2.10 per kWh. The conclusion of this project is that wind is the better choice because it produces the most energy, is slightly cheaper, and has the least amount of zero energy days. It was a tough choice. Solar was more consistent but had more zero energy days. Both had pros and cons but overall wind is a better choice for our weather conditions.

We did not consider where we would put our power plants, however. We researched solar and wind power systems and their cost, but not the specific costs of installation and maintenance. Also, we did not include how it would affect habitats. Future plans for this project are how it would work in other towns or cities, such as Moriarty or Albuquerque. Or, how would other renewable sources work in Edgewood, such as hydropower or biomass.

Introduction

The purpose of this project is to decide which energy source, wind or solar, costs less and can support Edgewood energy needs. We are only considering Edgewood residential electricity. We chose this project because of CO_2 emissions. Today, people use way too much coal and gas without caution. They use coal and gas without thinking about how it affects the environment. CO_2 emissions are causing global warming and an abundance of harm to animals and people. Of all the energy sources, coal emits the most CO_2. Gas and coal is also the leading energy source, but not in a good way. 73% of New Mexico's energy is generated by coal.

We decided that we should create a project to decide which energy source would be best for our hometown, Edgewood, New Mexico. At first we were going to compare solar and coal. But the answer was obvious, coal would be cheaper but solar would be far cleaner. So we thought about wind and solar energy. Which of these clean energy sources would cost the least and generate the most power?

Our hypothesis was that solar would output more energy and cost less. This is because in Edgewood, the sun shines 329 days out of the year. Wind in Edgewood was weaker and didn't seem like it would cause great power output. The monthly average wind speed in our town was only 14.5 MPH.

Research

Micro wind turbines are better than fossil fuels, tending to the needs of an average American family. Wind energy is one of the growing energy sources, rocketing in the USA and creating jobs. The jobs wind farms create are project managers, project coordinators, production managers, wind turbine technicians, wind turbine maintenance and many more. Wind turbines do great in the wind states such as Kansas.

Wind energy is a good alternative energy because it is safe. Wind energy is estimated to cost around $35,000-$50,000 installed per windmill .The disadvantages of wind energy sources are that the energy can jump and you would not know when it would happen. One of the advantages of wind energy is that it is energy efficient and it does not create global warming or CO2.

Many people find solar panels a great idea. Without making noise and being able to fit easily somewhere, solar panels are very convenient. Wind turbines however are noisy and take up a lot of space. Many people agree that wind turbines can also be hazardous, with it being able to jump electricity. But photovoltaic solar panels do contain toxic material. So both sources have their consequences.

When sunlight is absorbed by the panels the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the solar cells to produce electricity. This process of converting light (photons) to electricity (voltage) is called the photovoltaic (PV) effect. Solar cells are typically combined into panels that hold about 40 cells, they are normally placed on buildings or hill tops that get lots of sun throughout the day; the sun is normally out for about 11 hours a day (with no cloud interference that is). Thin solar cells use layers of materials only a few micrometers thick. Thin technology has made it possible for solar cells to now double as rooftop shingles, roof tiles, or the glazing for skylights or atria. The solar cell version of items such as shingles offer the same protection and durability as ordinary asphalt shingles .Solar panels cost 14 thousand dollars and some electric companies pay you to produce your own power!

Solar cells are also efficient. The meaning of solar cell efficiency is the percentage how much sunlight hits a cell and then is converted to electricity. The efficiency of the solar panel is always less than the efficiency of the solar cells that are packed into the module. This most likely because glass is put on top of the cells to protect them and glass reflects sunlight, so not all the sunlight reaches the cells. Let me tell you this before we get into this, the higher efficiency, the more it costs so........ Anyways, the companies with the highest cell efficiency are Sanyo and California Sun Power. Before I tell the formula for this let's start off with something easy. Let's say one thousand watts of light is shined directly onto a cell, the cell will generate two hundred twenty-two watts of electricity. Then the efficiency of the cell will be 22.2%. So the formula is 222 divided by 1000 equals 22.2%.

Description

This project's purpose is to determine which is better for Edgewood, wind or solar energy. By saying which is better, we mean which costs less and outputs more energy. Possibly after further research, we can test our project on other cities.

We did not consider if it would affect animals. We also did not include who might provide the money for our project. Our project does not include where we placed our turbines or panels. We did not plan out all maintenance costs.

We made two Starlogo TNG models; one for wind and one for solar. We wrote code based on research. Then we ran the program for six years and that is how we got our results. All we used was research, Starlogo TNG and a computer.

We had help from local resources. We got information from the Sandia Airpark and our Edgewood Weather Station, N5KJT. We found that did not give us enough information, so we also used the Mountainair Weather Station We met with regional science fair judge John Ball who helped us on our board and program. We met with Greg Nielson, an expert in solar research at Sandia Labs to learn about solar energy.

We made two programs to test how solar energy and wind energy would work in Edgewood. We did this to decide how to figure out how we could solve our problem. We put our research into our model, we measured the costs for our amount of solar panels and other equipment and wind turbines needed. To make our program accurate, we researched Edgewood weather and put variables and procedures in to determine our results based off of Edgewood weather. It was just like putting up a real solar power plant and wind farm and testing and see how Edgewood weather would effect it and how much energy would it output. Our programs have a timekeeper to track days and months. We can simulate one year of time on our model. Then we ran the program for six years and that is how we got our results.

We determined Edgewood's energy needs by doing research. Edgewood has 1,430 homes and each home needs an average of 630 kWh per month. We discovered that we needed 10,810 MWh of electricity. So we calculated how many solar panels or turbines we needed to provide that much energy.

Solar Program and Model

We used the solar calculator on National Renewable Energy Labs Renewable Resource Data Center to plan our solar plant. We wanted our model to act like a real solar plant and we wanted to know how much it would cost. We decided that a solar power tower was too big for our town of Edgewood, so we used photovoltaic panels. Based on our location we calculated that we need a 5 MW system. We chose to use 250 W solar panels.

5MW divided by 250 W panels = 20,000 panels total.

20,000 panels times $237.50 = $4,750,000 for all panels.

Off grid inverters = $4510 times 439 inverters = $1,979,890. Each inverter handles 11.4 kW so 5 MW divided by 11.4 kW = 439

Zomeworks Passive Track Rack holds 9 panels and costs $4,182.

20,000 panels divide by 9 panels per rack = 2,223 racks.

2,223 racks times $4,182 = $9,296,586.

Total cost of our solar power system is $16,026,476.

This system is the basis for our solar model.

Our solar model started with the seasonal change model from GUTS, written by Joshua Thorpe. We then put clouds in the seasonal change model. The seasonal change model taught us how to use list variables to track the month, year, time (day or night) and energy that the solar power plant produces. We also put in a part to make it look like it is turning day and night. We also put in a procedure so that it will create clouds, and it will kill the clouds at the end of the day. We made a setup column so that it creates the solar array and the sun. It also creates the data tables. We created the tables so it can track the solar power. We also created the forever block so that the program runs forever so we can track it for as long as you want it to. But we didn't program it for cost or for when a solar panel dies and that cost money. We put in randomness so that it doesn't always end up with the same data every time. We ran our program six times, which is like six years to get the data that we have now. The weather maker tells us if there are clouds or no clouds and if there are clouds there is no energy those days. Partly cloudy days are counted as zero energy days too. Also in the setup there is a list variable with overcast days that stores the average number of cloudy days in every month from January all the way to December.

The weather maker gets the data for if it's going to be an overcast day by using a probability of average number of cloudy days (9 in January) to number of days in the month (30). If cloudy, it won't make energy that day and sets cloudy = 1 or true. The program then hatches clouds. If cloudy =0 or false, then the solar array will create energy. We get the solar resource for the month in kW (**maps.nrel.gov/prospector-solar resource**) and multiply it by the area of the solar panels (32,842 square meters) and multiply it by the efficiency of the panels (.15) and multiply by the DC to the AC conversion factor (.77). This is our mathematical model. At the end of the day we reset the energy so we can track the next day.

Wind Program and Model

We found our Wind data by finding information from Edgewood weather station N5KJT which gave us the monthly mean wind speed at 10 meters. We had to adjust the wind speed for 50 meters by multiplying it by 1.3. We confirmed the adjusted annual mean wind speed for Edgewood on a National Renewable Energy Laboratory wind map at 50 meters and the two numbers agreed. We got additional information from the Mountainair weather station that breaks down wind speeds into percent of time at different ranges. We needed to know how many days there would not be enough wind to start the turbines. We also visited the New Mexico Wind Energy Center to learn about wind energy.

We determined the Edgewood residential electricity needs by doing research. Edgewood has 1,430 homes and each home uses an average of 630 kWh per month (U.S. Energy Information Administration, New Mexico data). We are confirming that data with electricity bills. We calculated that Edgewood needs 10,810 MWh yearly.

We chose a wind turbine for our wind farm, the WES 30, a 250 kW two-blade turbine with low cut-in speed. We looked at the energy production graph for our wind turbine and the average annual wind speed for Edgewood, which is 6.5 meters per second. From the graph we estimated that each turbine would generate 600 MWh per year. Then,

10,810 MWh divided by 600 MWh = 18 turbines.

Each turbine costs $1,040,585. When multiplied by 18, equals $18,730,530. This is the total price of our wind farm. Our project didn't include the installation or maintenance price.

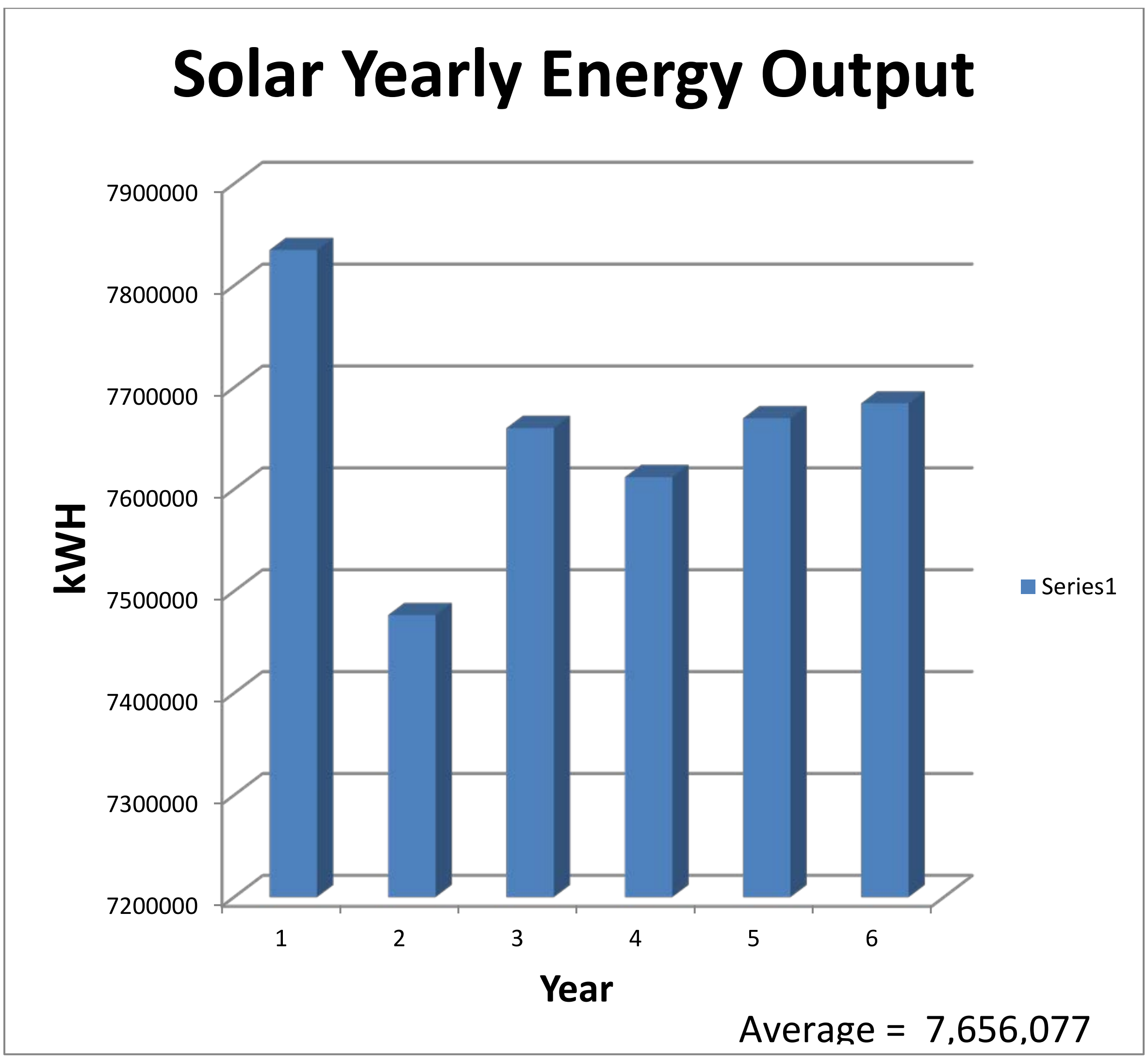
Our project started with a program from the GUTS website. It was called Seasonal Change Model and made by Joshua Thorpe. It first started out with an agent called the updater and it would change the ground color for each season. We had some problems with the terrain not changing but we tweaked it and made it better. We then took out some of the blocks, but put some in also. We put weather into the model by putting average wind speed for each month in a form of a list variable. Then, we put some randomness into the project by putting in that 20% of the time there is no wind at all, but 80% of the time there is power. Since there is 20% of the time there is no wind, then it is just saying that there is no power that day. We put in zero energy days to keep track of it. 80% of the time you will have energy.

To add randomness to the weather, half the time the program adds 1 m/s to the average wind speed. The other half of the time, our program subtracts 1 m/s. This is to vary the wind speed above and below the average. In our setup column, we have a list named Wind Speed (WS) Energy. For each block connected, it counts from 1 m/s. The last block is 10 m/s. So for each wind speed in our average wind speed list equals the energy on the list. The wind speed energy list shows how much energy is produced for each wind speed. We included a Google Earth image of Edgewood for our terrain. On top of the terrain we put a wind farm also. We made it so that in each month there is 30 days. The days don't reset whenever you go to another month, it just keeps on counting. The months go 0-11 not 1-12. We got our data from New Mexico State Hydrology site that gave us the average wind speed for each month. That is how we got our wind speed.

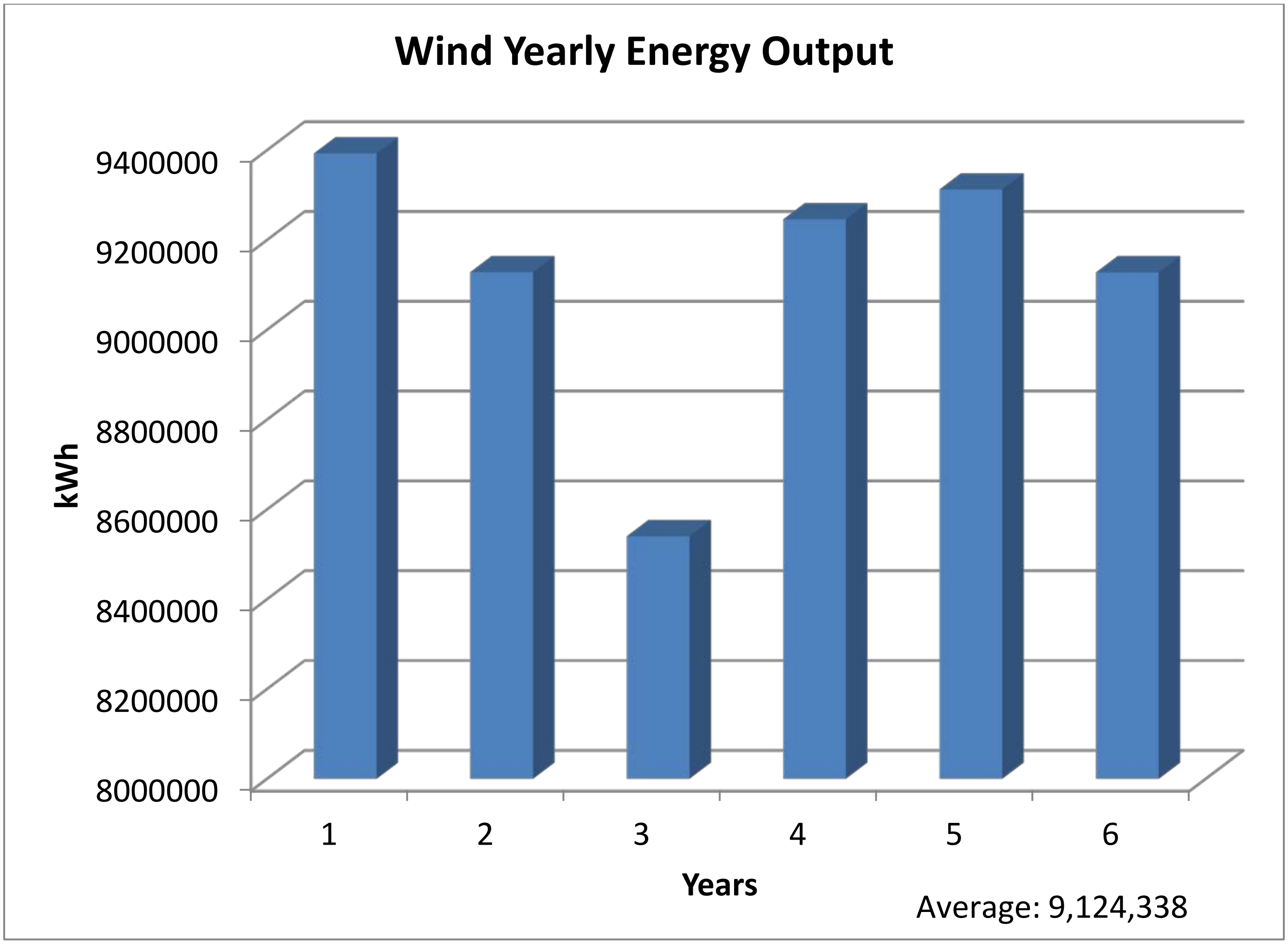
We ran the program 6 times. Each run is representing an entire year. We used our table and zero energy days monitor to keep track of the yearly data. We put it into an Excel Spreadsheet and then made the graph. We collected our data by running our program 365 days (on the spreadsheet it says 366 because it counts by twos) and going by what our power table and zero energy day monitor counted for that year. Our updater agent is our clock and calendar. In the timekeeper procedure it counts the days and makes sure that the days keep counting. The wind turbine agent decides how much energy is produced. For our wind turbine agents, we uploaded models from Google 3D Warehouse. We had to set file permissions for each computer to download stuff on it. We had to download three different files types, .kmz, .zip, and a .jpg. We would find an image that would look like our agent, download it and input it in the model. Tough but we got it.

Results

Annual Energy

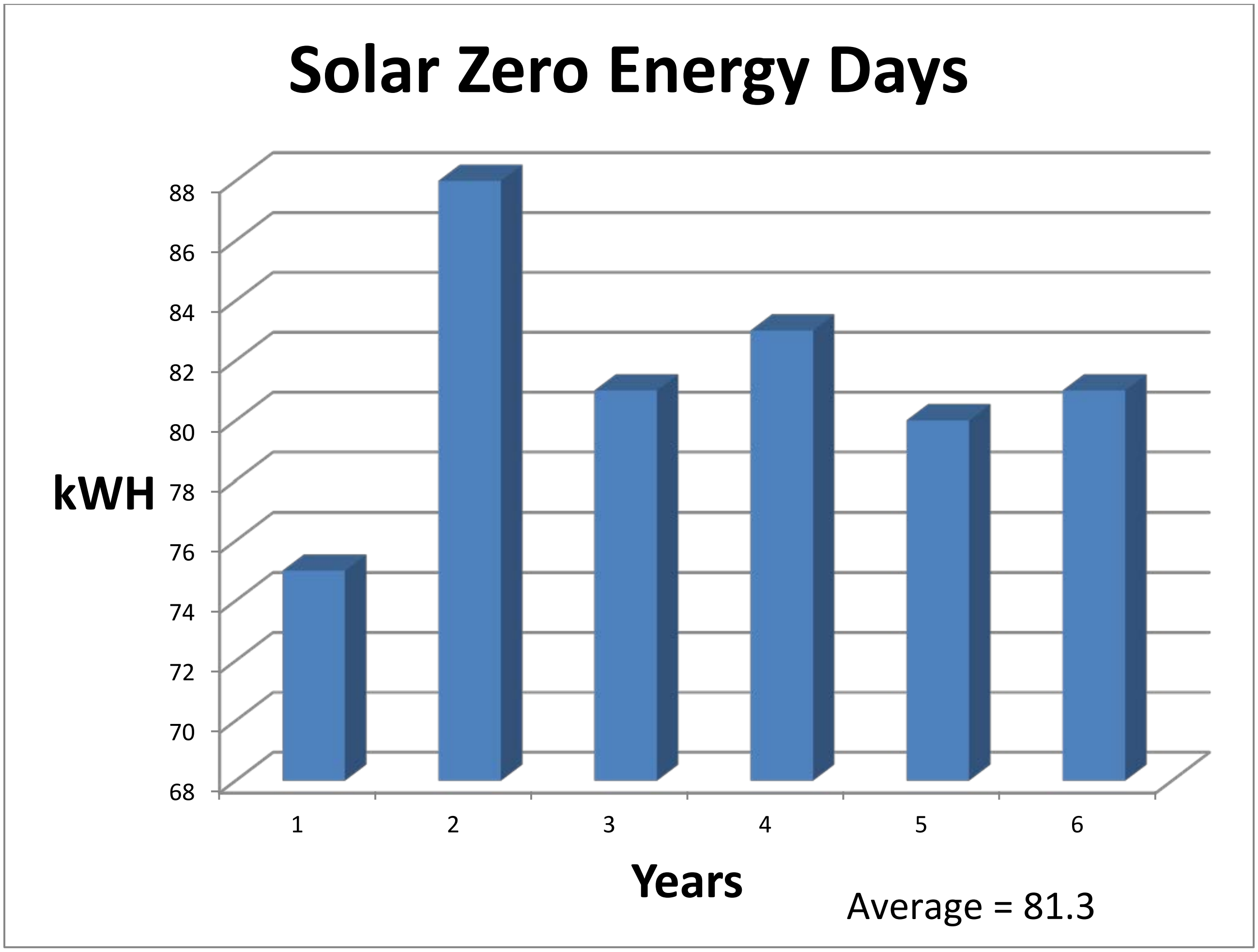


This graph shows the yearly energy output from solar. The average yearly output is 7, 656,077 kWh.

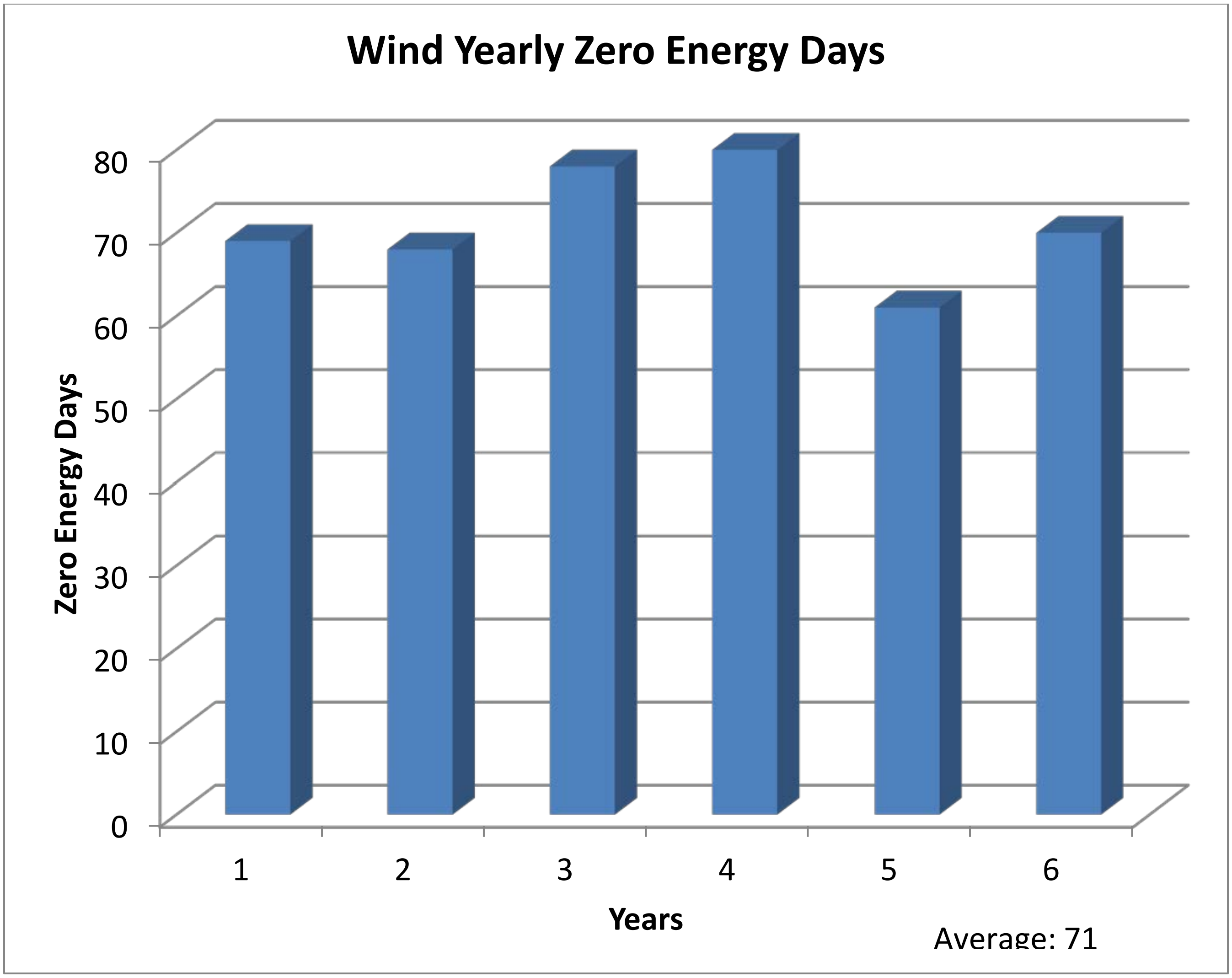


The average yearly energy output from wind is higher than solar. It is 9,124,338 kWh.

Zero Energy Days

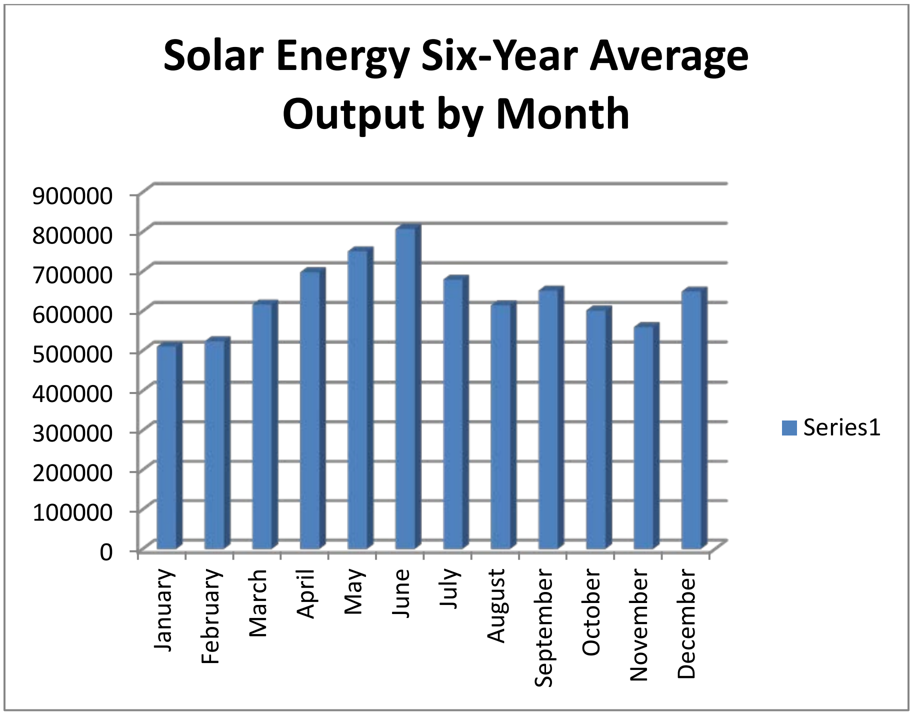


Zero energy days are when there is not enough sun or wind to make energy. Solar has an average of 81.3 zero energy days over six years. That includes days that are either cloudy or partly cloudy.

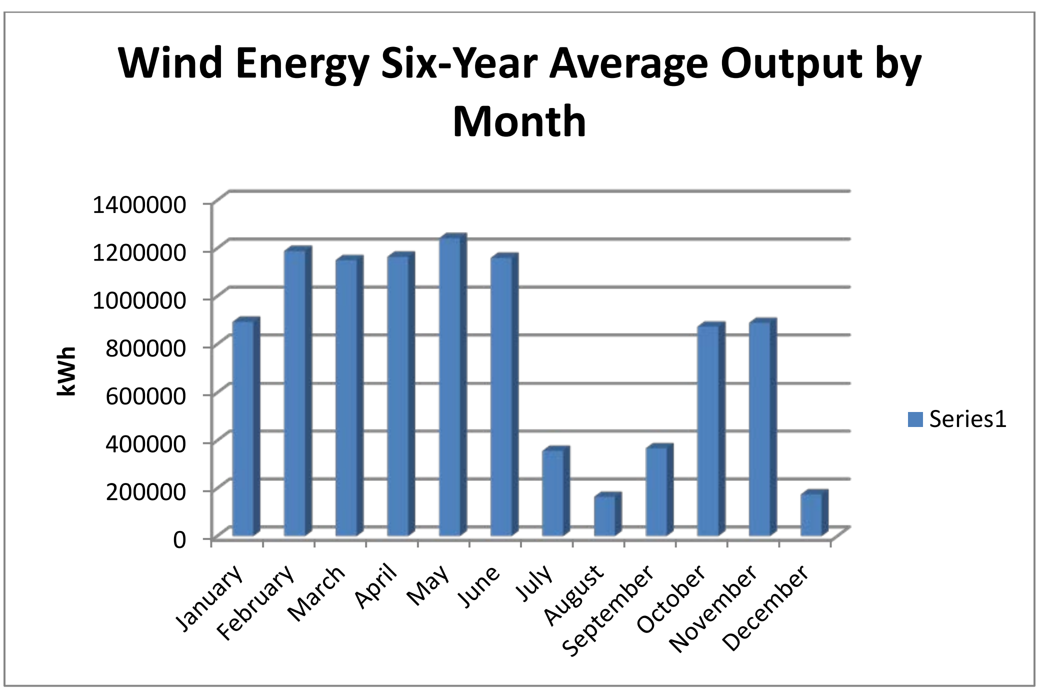


Results for wind power are 71 zero energy days, about ten fewer than solar.

Monthly Energy Output



The monthly solar power output is highest in June and lowest in January. This graph shows the average monthly power in kWh.



The y-axis numbers are higher on this graph. Maximum wind power is in May and the least is in August.

Conclusion

The conclusion of this project is that wind is the better choice because it produces the most energy, is slightly cheaper, and has the least amount of zero energy days. It was a tough choice. Solar was more consistent but had more zero energy days. Both had pros and cons but overall wind is better. Our hypothesis that solar power would work best in Edgewood did not prove to be true. The average zero energy days for wind is 71 days, while solar is 81.3 days. The average wind yearly energy output is 9,124,338 kWh. Solar is 7,656,077 kWh. The peak energy output of wind is May while solar is June. Wind is $2.05 per kWh and solar is $2.10 per kWh. We found out that January and December are the highest usage months for Edgewood but the rest of the months are around the same usage. This surprised us because we thought the highest demand would be in the summer. The average electricity use by month is 591.1 kWh. The lowest month of electricity use is October. This is based on gathering information from our electric bills.

Personal Statement

Alyssa Stokes: This project has definitely pushed my brain. I worked so hard for this project and I hope we get a great rating. It was also fun being with my friends and working together as a team.

Judy Zamora: The project was very fun and interesting, I liked that we had just picked a random topic and when we started researching on our project and found out more about we liked doing it, we enjoyed it while we were doing it. We never gave up

Nicholas Cox: I think that this project was one of the most interesting projects I have ever done. And the field trips were my favorite part. I have also learned a lot.

Riley Otto: I thought it was fun and I learned about solar and wind.

Aaron Talamante: This project was amazing. I loved that we researched and did a whole project on something that is destroying our Earth. The best part about this was when we first presented at the evaluation, it was so fun.

Acknowledgements

We would like to thank these people for helping us with this project.

Greg Nielson, Sandia Labs
Nick Bennet, Programmer
Our wonderful principal, Mrs. Dray
Our PTO, who payed for our gas to travel
Our teacher, Mrs. Thompson
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Eric Chavez, New Mexico Tech Student
Stanley Engle, New Mexico State University
Ruth McGuigan, Horizon Renewables in the United Kingdom
Alyssa Christy, Sandia Labs
Evelyn Christy, Edgewood Elementary Teacher

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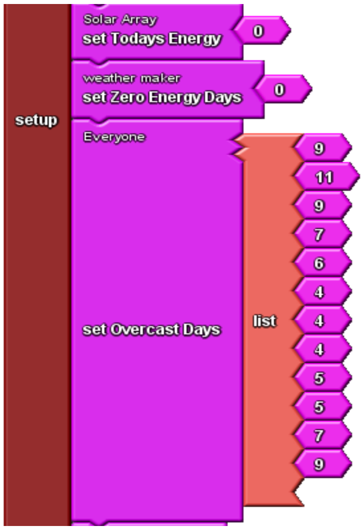
Appendix

Solar Program Documentation

Setup 1

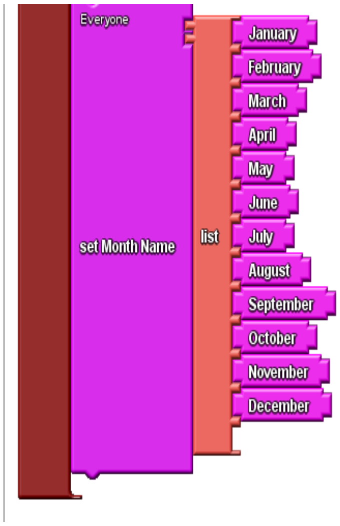
Here we set up our agents and variables initial condition.

Setup 2



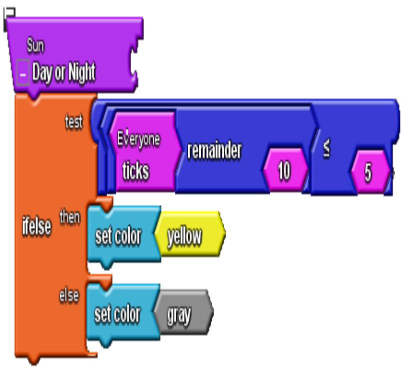
The overcast days is a list variable and lists the average number of cloudy days are in each month starting at January.

Setup 3



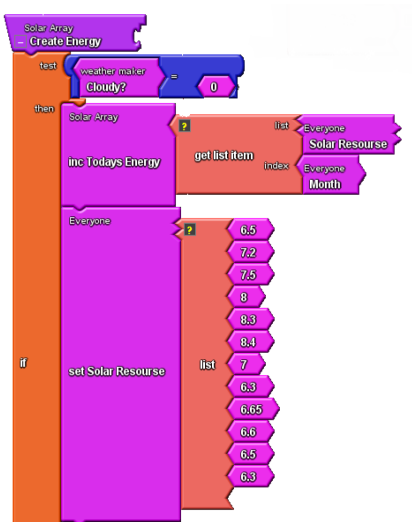
Here is where a list variable (month name) sets the name of the months in the program.

Sun 1



This is a procedure for our sun and it tells it to turn into the moon after 5 out of 10 ticks in the day so that no energy is created at night. It is daytime half of the time.

Sun 2

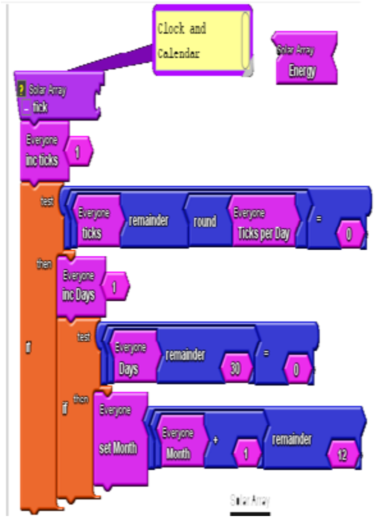


This is where the energy from the sun is counted. The first part is telling if the day is cloudy no energy is created. The next part is telling the average solar radiation each month.

Sun 3

This part generates the energy from the solar panel into energy on the grid that we can use. The bottom part tells when the ticks reset and a new day is started.

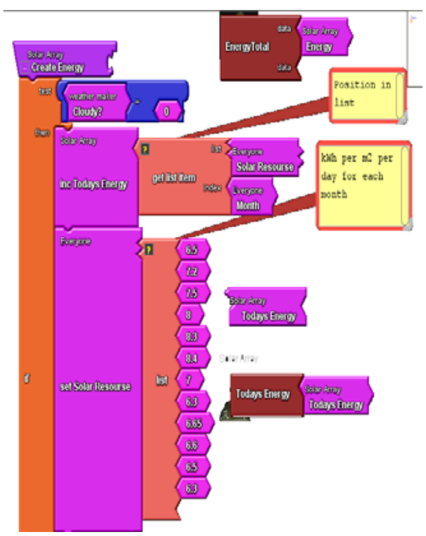
Array 1



There are 30 days in a month until the program sets to a different month.

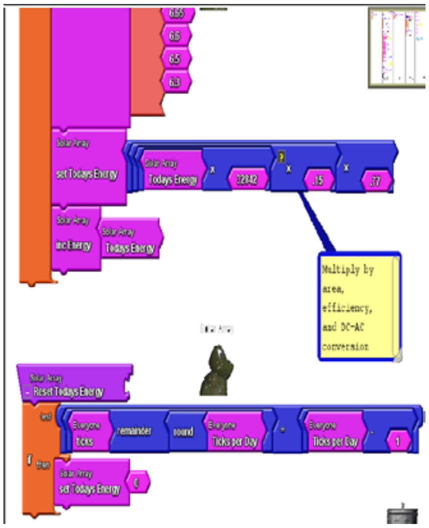
This keeps track of days and months.

Array 2



If it’s not cloudy, we get the solar resource for the current month.

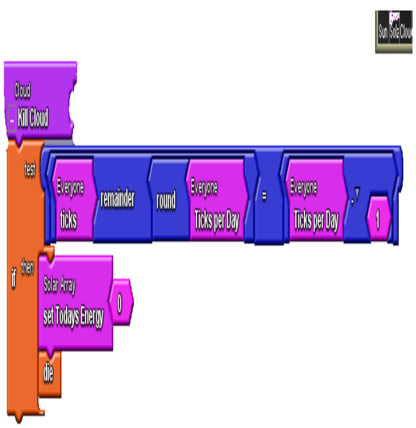
Array 3



Solar radiation is multiplied by the area and efficiency of the panels, and the DC to AC conversion factor.

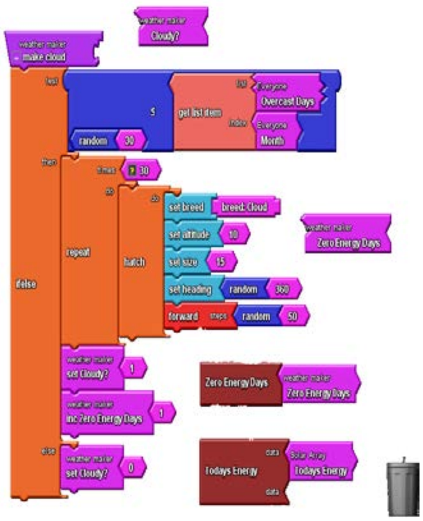
At the end of the day, reset energy to zero.

Cloud



This is telling the clouds to die when the day is done.

Weather Maker



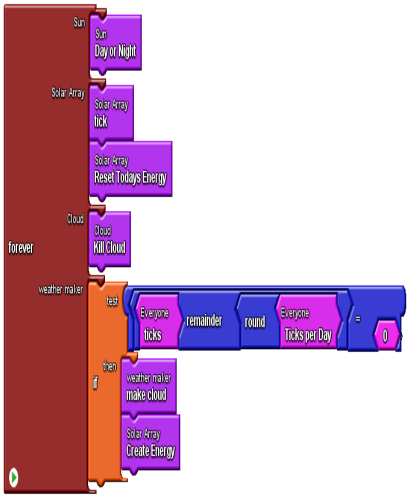
Randomness is added to the weather here. The chance of a cloudy day depends on the average number of overcast days for that month. If it's cloudy, this will hatch some cloud agents to block the sun and set cloudy = 1, or true.

Everyone

These are all the variables and monitors that are created.

This displays the month name in Spaceland.

Runtime

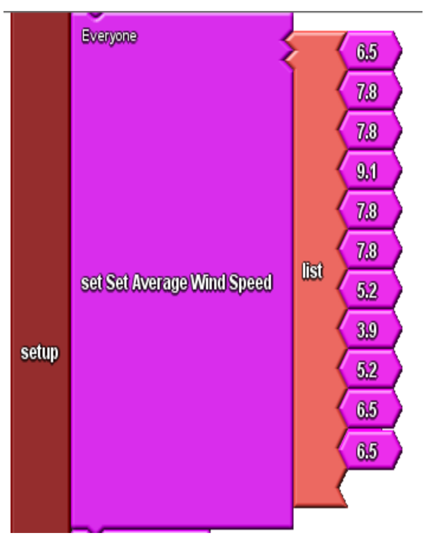


This puts all the procedures into action in the program.

Setup 1

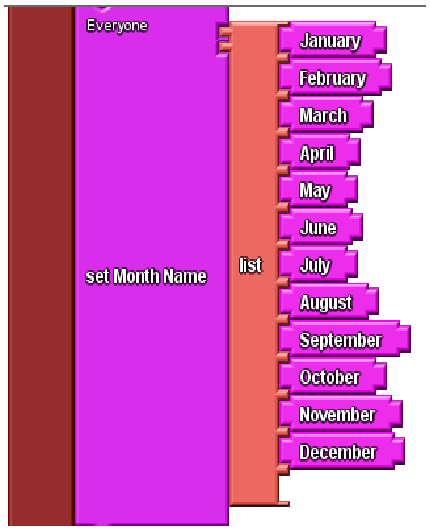
Here we set up our agents and variable initial conditions.

Setup 2



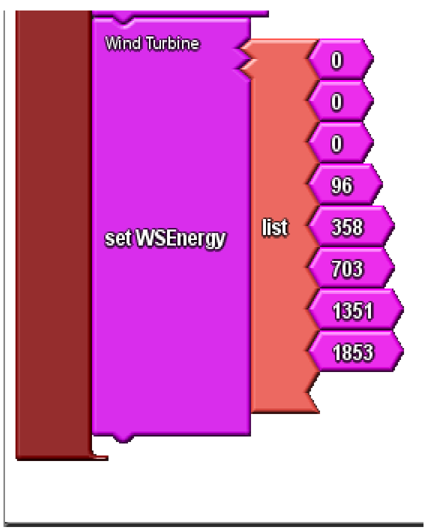
This list variable contains the monthly average wind speeds for January- December at 50 meters high.

Setup 3



Here is a list variable with month names. This displays the month name in Spaceland.

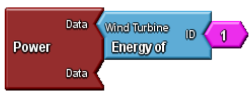
Setup 4

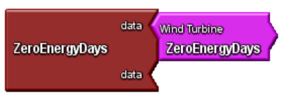


This is a variable which listed the energy output for wind speeds from 1-10 m/s.There is zero energy at less than 4 m/s.

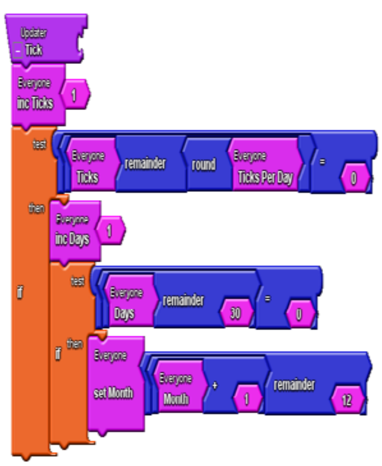
Setup 5

These tables graph our data.



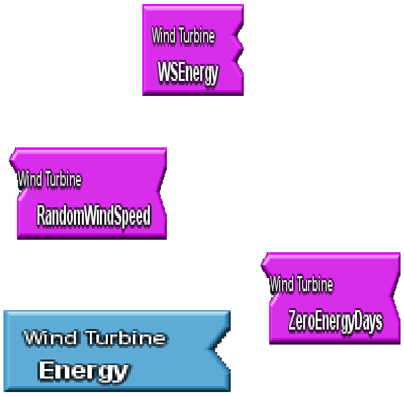


Updater



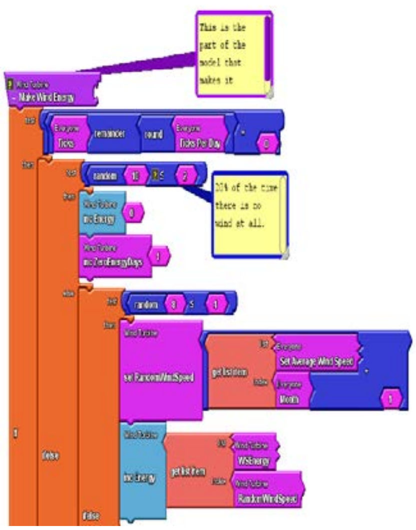
This is a timer. It counts the months and days.

Wind Turbine 1



These are variables for the wind turbine. WSEnergy is a list variable for the energy generated at different wind speeds. RandomWindSpeed is the monthly wind speed plus or minus . ZeroEnergyDays is incremented whenever the wind is less than 4 m/s. Energy is an agent variable tracks the total energy per year.

Wind Turbine 2



This is where the wind turbine creates energy. Power is created once a day. There is a 20% chance that there will be no wind that day.

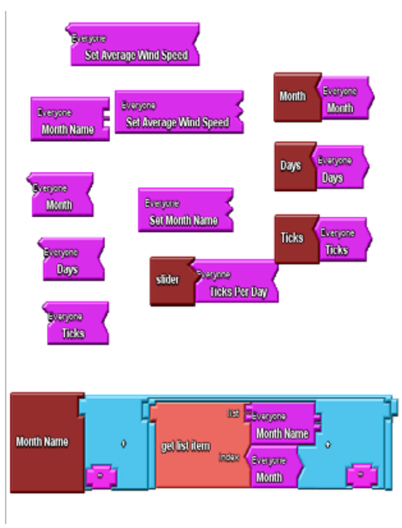
We add randomness to the program. There is a random chance of adding 1 m/s or subtracting 1 m/s to the wind speed.

Wind Turbine 3

The RandomWindSpeed is the index of the list to get the energy generated that day.

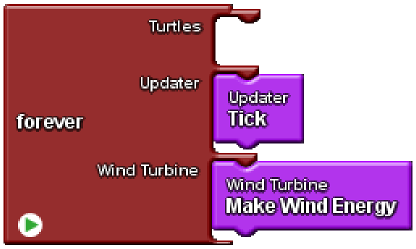
This is the zero energy days monitor.

Everyone



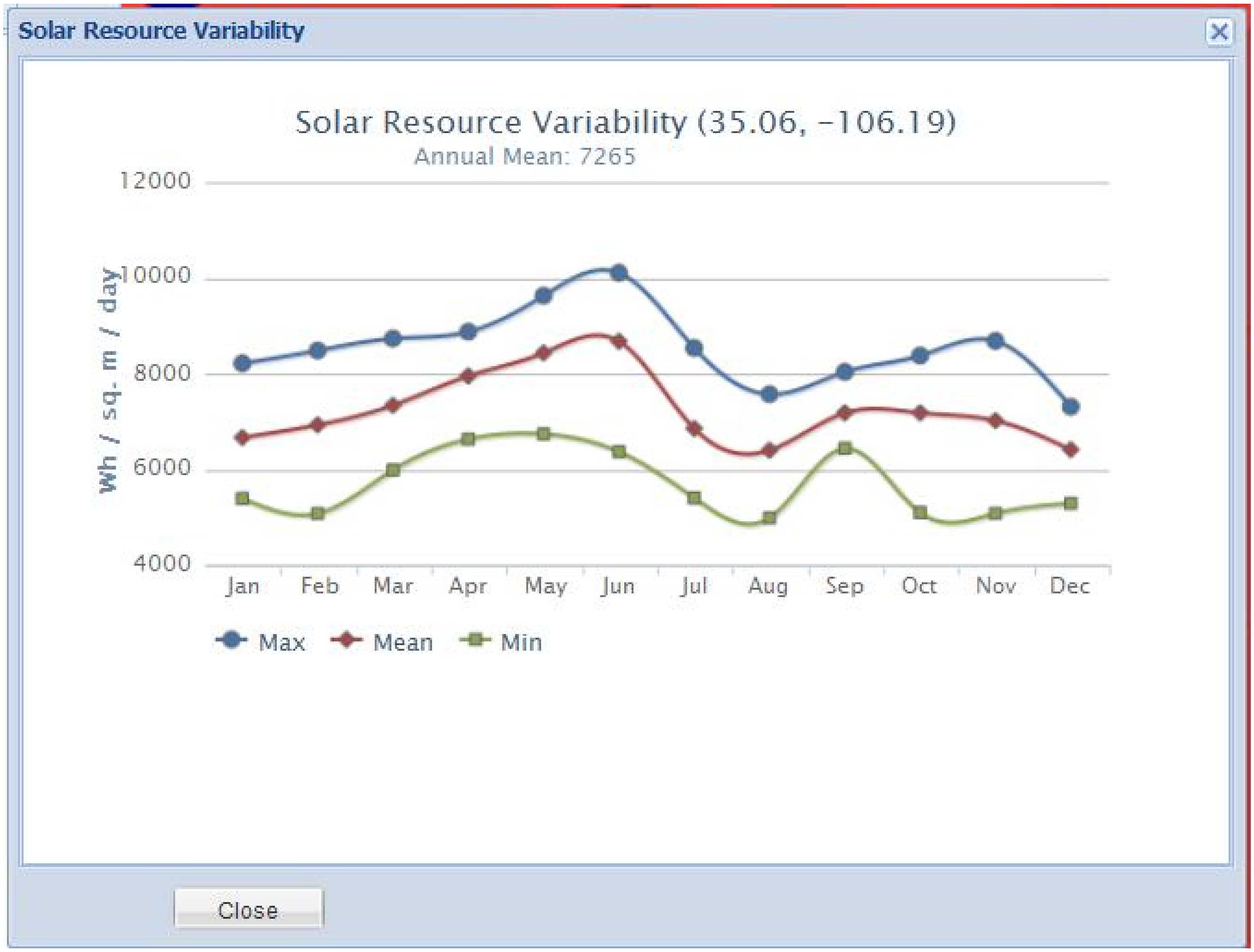
These are the sliders, monitors and variables for the time tracker.

Runtime



This is where the procedures are set to run.

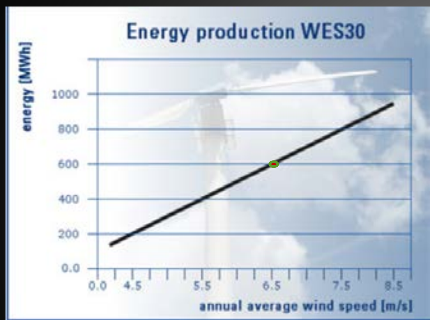
Solar Research

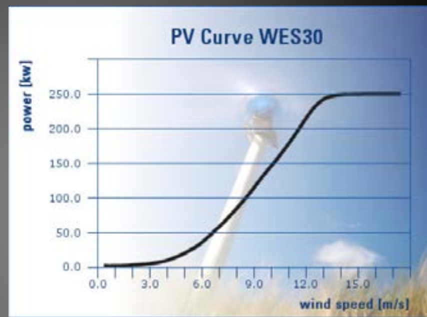


The figure above of Solar Resource Variability is how we got our information about solar radiation in Edgewood, NM. It is from the National Renewable Energy Lab's Solar Prospector website.

Wind Research

Wind Mathematical Model





Estimated 600 MW/h year at our annual wind speed

Monthly Calculations for model
Used for daily information
Converted mph to m/s

These graphs from our wind turbine gave us data to estimate how many turbines we needed and how much power is generated at different wind speeds.

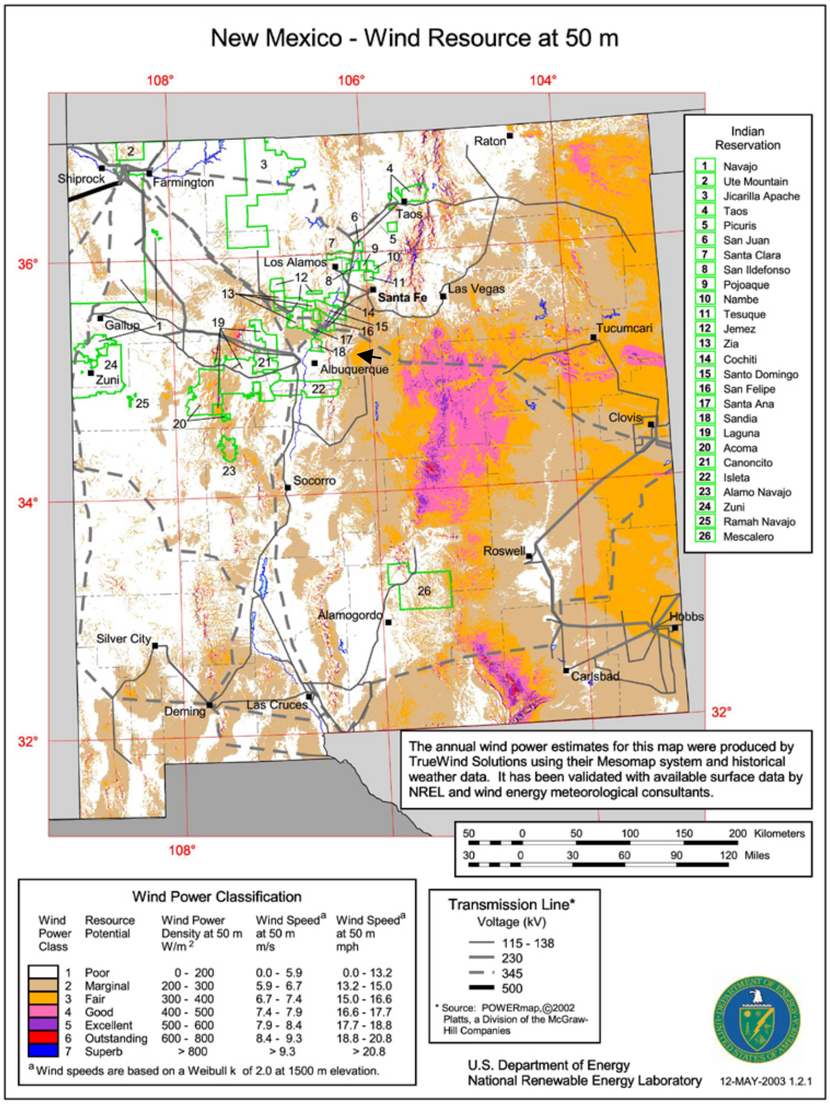
Wind Math Part 2

- Power = ½ dAS^3
- S = wind speed so a small increase results in big power increase
- d = density, decreases as altitude increases
- A= swept area of blades
- A= πr^2 so a small increase in blade radius is a big increase in area

Report for N5KJT Edgewood
From January 2000
to December 2012

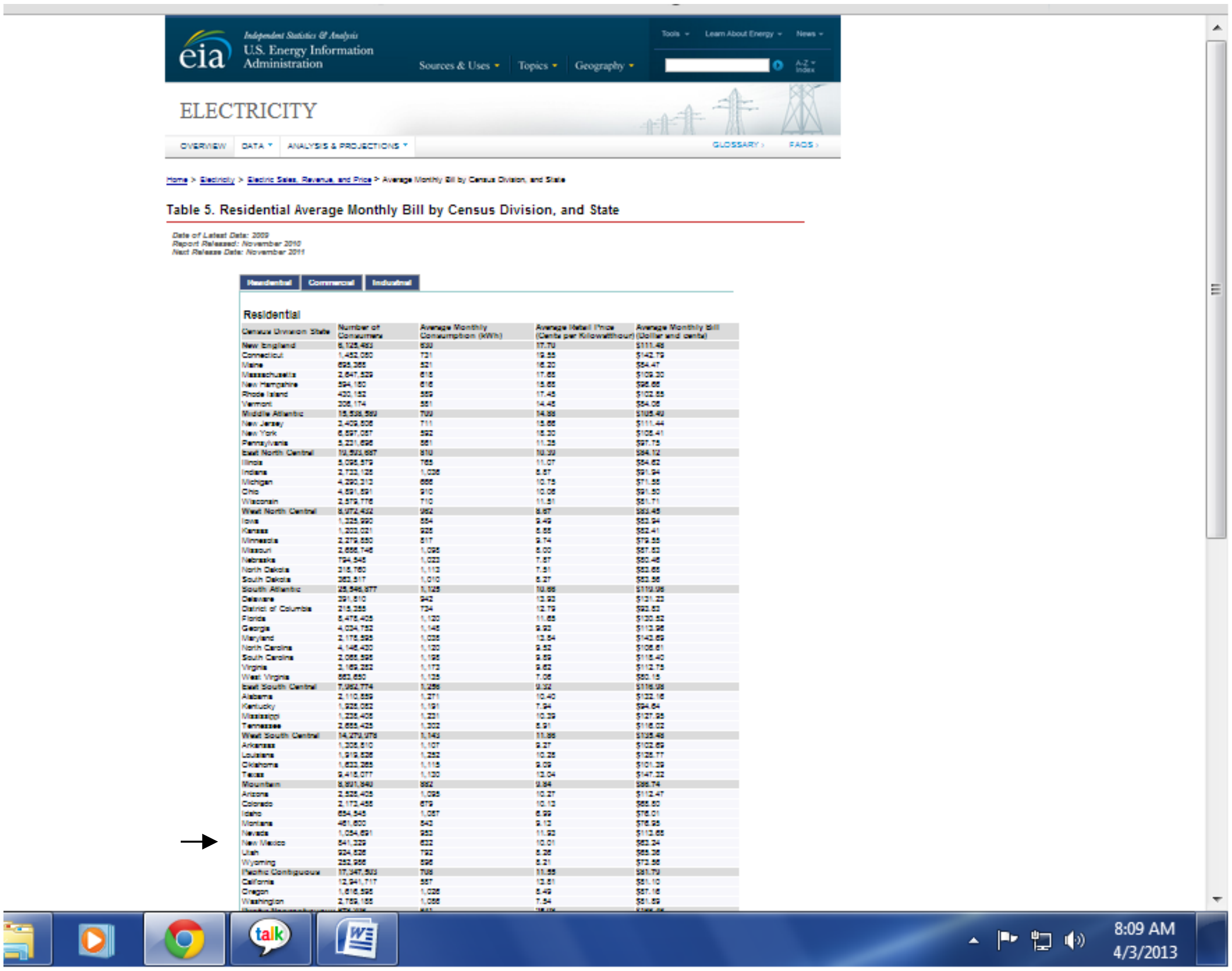
Month	Temperatur Max F	Temperatur Min F	Temperatur Mean F	Windspeed Max mph	Windspeed Min mph	Windspeed Mean mph
January	42.426	21.557	31.026	15.525	7.000	11.333
February	45.409	23.364	33.841	18.318	7.955	13.391
March	59.887	30.790	44.838	20.242	7.274	13.673
April	66.200	37.745	52.282	22.000	6.945	14.531
May	70.726	43.565	57.653	20.903	8.113	14.297
June	84.000	54.875	70.362	19.031	6.750	12.602
July	82.824	60.941	72.248	12.235	4.000	8.044
August	81.000	58.484	69.887	9.387	3.323	6.382
September	72.600	50.033	61.010	12.167	4.000	7.975
October	62.290	39.710	50.277	14.387	4.871	9.384
November	48.143	26.714	36.434	17.531	6.327	11.724
December	40.600	23.183	30.895	14.983	5.517	10.165

Our nearest weather station gave us monthly average wind speeds at 10 meters. We multiplied by 1.3 to get wind speeds at 50 meters (Gipe, Paul).



We confirmed our annual average wind speed using this map. The black arrow points to Edgewood and shows 6.7 to 7.4 meters per second.

Electrical Usage



Home > Electricity > Electric Sales, Revenue, and Price > Average Monthly Bill by Census Division, and State

Table 5. Residential Average Monthly Bill by Census Division, and State

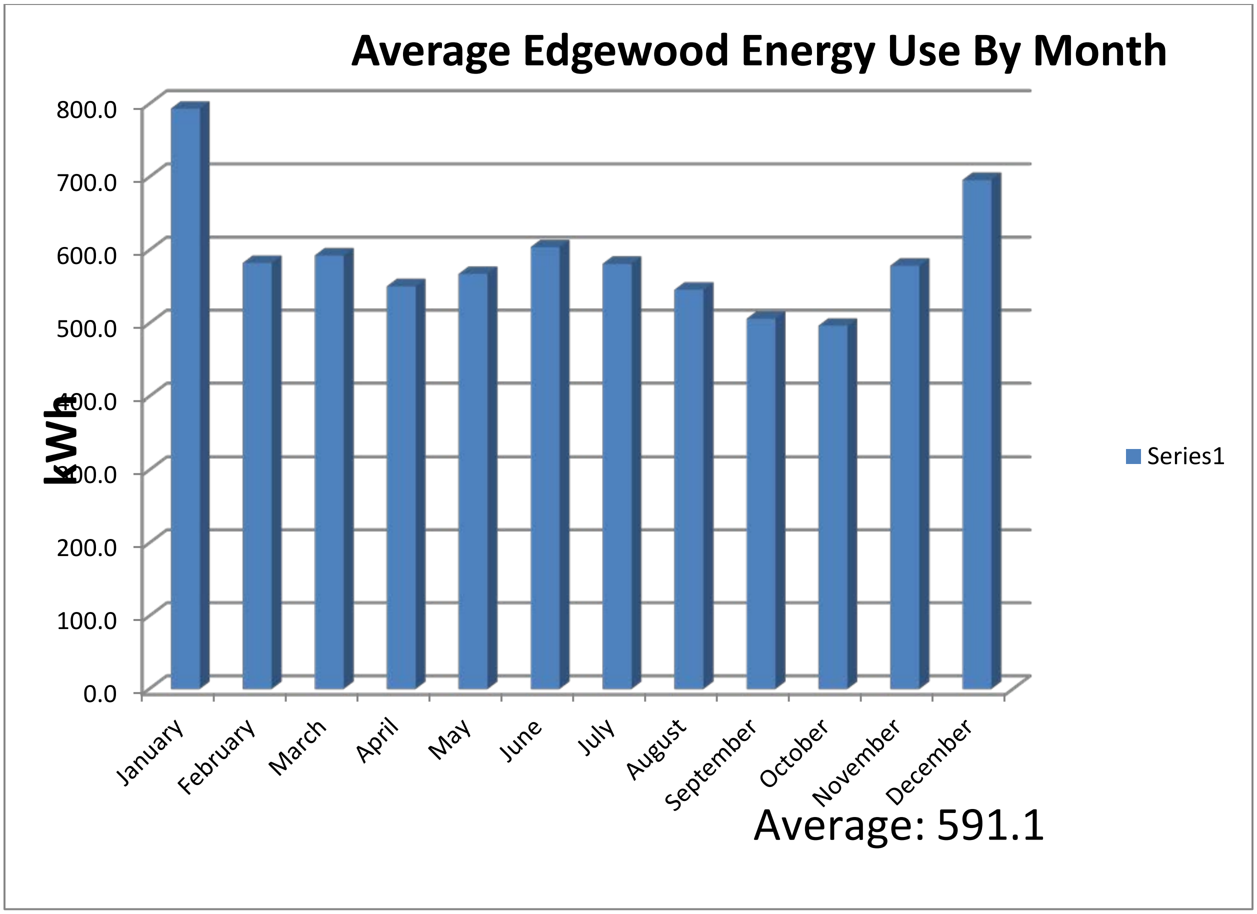
Date of Latest Data: 2009
Report Released: November 2010
Next Release Date: November 2011

Residential | Commercial | Industrial

Residential

Census Division State	Number of Consumers	Average Monthly Consumption (kWh)	Average Retail Price (Cents per Kilowatthour)	Average Monthly Bill (Dollar and cents)
New England	6,125,463	630	17.70	$111.48
Connecticut	1,452,080	731	19.55	$142.79
Maine	695,365	521	16.20	$84.47
Massachusetts	2,647,529	615	17.65	$109.30
New Hampshire	594,150	616	15.65	$96.66
Rhode Island	430,152	589	17.45	$102.85
Vermont	306,174	581	14.45	$84.06
Middle Atlantic	15,538,589	709	14.88	$105.49
New Jersey	3,409,506	711	15.66	$111.44
New York	6,897,087	592	18.30	$108.41
Pennsylvania	5,231,696	861	11.35	$97.75
East North Central	19,593,687	810	10.39	$84.12
Illinois	5,096,579	765	11.07	$84.62
Indiana	2,732,125	1,036	8.87	$91.94
Michigan	4,290,313	666	10.75	$71.58
Ohio	4,891,891	910	10.06	$91.50
Wisconsin	2,579,776	710	11.51	$81.71
West North Central	8,972,432	962	8.67	$83.45
Iowa	1,325,990	884	9.49	$83.94
Kansas	1,203,021	925	8.88	$82.41
Minnesota	2,279,850	817	9.74	$79.55
Missouri	2,656,746	1,098	8.00	$87.83
Nebraska	794,545	1,023	7.87	$80.48
North Dakota	318,760	1,113	7.51	$83.65
South Dakota	363,517	1,010	8.27	$83.56
South Atlantic	25,546,877	1,125	10.66	$119.96
Delaware	391,810	942	13.93	$131.23
District of Columbia	215,285	734	12.79	$93.83
Florida	8,478,405	1,120	11.65	$130.52
Georgia	4,034,752	1,145	9.93	$113.96
Maryland	2,176,898	1,038	13.84	$143.69
North Carolina	4,146,430	1,120	9.52	$106.61
South Carolina	2,068,898	1,198	9.89	$118.40
Virginia	3,169,282	1,173	9.62	$112.75
West Virginia	863,850	1,135	7.06	$80.15
East South Central	7,962,774	1,256	9.32	$116.98
Alabama	2,110,859	1,271	10.40	$132.16
Kentucky	1,928,082	1,191	7.94	$94.64
Mississippi	1,236,408	1,231	10.39	$127.95
Tennessee	2,685,425	1,302	8.91	$116.02
West South Central	14,279,978	1,143	11.86	$135.48
Arkansas	1,308,810	1,107	9.27	$102.69
Louisiana	1,919,826	1,252	10.28	$128.77
Oklahoma	1,633,265	1,115	9.09	$101.39
Texas	9,418,077	1,130	13.04	$147.32
Mountain	8,891,840	882	9.84	$86.74
Arizona	2,528,405	1,095	10.27	$112.47
Colorado	2,173,458	679	10.13	$68.80
Idaho	654,545	1,087	6.99	$76.01
Montana	481,600	842	9.13	$76.95
Nevada	1,054,691	953	11.93	$113.68
New Mexico	541,329	632	10.01	$63.24
Utah	924,526	792	8.26	$65.36
Wyoming	252,958	896	8.21	$73.56
Pacific Contiguous	17,347,503	708	11.55	$81.79
California	12,941,717	587	13.81	$81.10
Oregon	1,616,598	1,026	8.49	$87.16
Washington	2,789,188	1,088	7.54	$81.89

New Mexico's monthly average electrical consumption is 632 kWh for residential.



This graph shows Edgewood electricity usage from 10 years of electrical bills from five different households in the Edgewood area.