How Climate Change Affects Power

Outages and the Distribution of Power

New Mexico

Supercomputing Challenge

Final Report

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Team 3

Multi-Schools (MHS, EHS)

Team Members:

Nancy Avila	navilad.735@gmail.com
Candis Canaday	candisc101@gmail.com
Gwenevere Caouette	gweneverecaouette@gmail.com
Kyreen White	hellu.kittycat2004@gmail.com

Teacher(s):

Ms. Lunsford	lunsford@aps.edu

Sponsor:

Mrs. Glennon	kglennon25@gmail.com
Patty Meyer	pmeyer2843@gmail.com

Mentor(s):

Jack Ingalls	jack.ingalls@pnm.com

Areas of Science: Environmental Science

Table of Contents

Executive Summary

We began our project with a vague idea that we wanted to work on something that had to do with global warming. We researched this topic and limited it down to the effect of global warming on the power grid. From there, we found a mentor, Jack Ingalls, with PNM who was able to help us better understand the mechanics of the power grid and how it moves electricity from place to place. From what we learned, we developed our code to show power moving from the sources to its destination.

Within our code, we used turtles to show the current and the way it travels through the power grid. It starts off in the power plant and makes its way to the house. There are sliders for temperature and current. These sliders represent the slow down that the power grid can experience in unpredictable weather patterns that can be increased due to the effects of global warming. With this model, one is able to understand the time it takes for electricity to travel based on the demand. As temperature increases, the demand for electricity increases. As electricity increases, CO2 and climate change increases. As climate change worsens, the Earth's temperature increases and the cycle continues.

Problem Statement

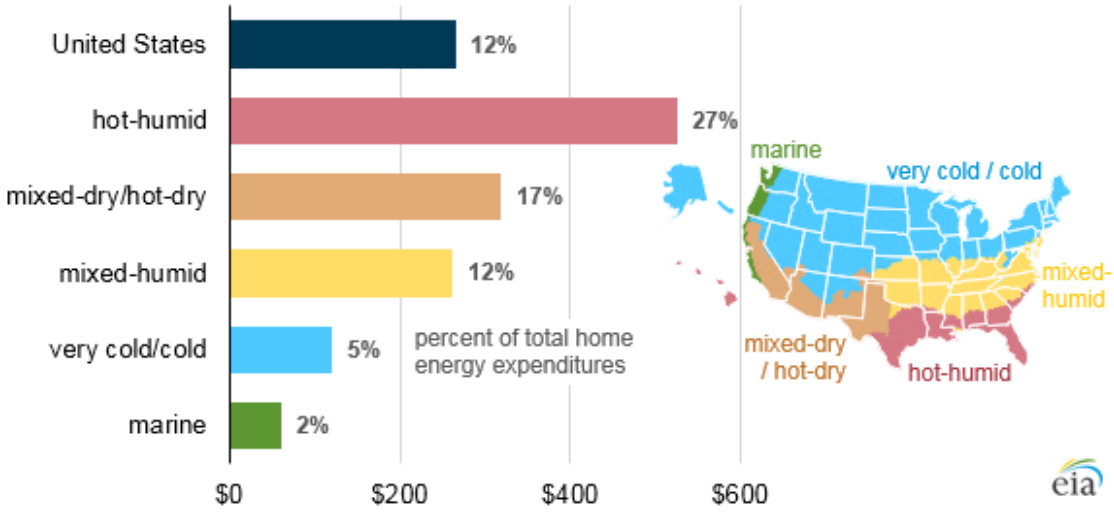
With the increase of CO2 and heat in our planet, many issues caused by climate change have surfaced over the years. With added heat in the planet, many more power outages have been present. As temperatures increase, the need for cooling increases which stresses the power grid. Around 90% of power outages result from failure in electrical distribution systems and poor planning. If poor planning and climate change is an issue with the power grid and its

functionality, what can be done to further prepare power plants to transition into resourceful energy sources.

The idea of our problem came from climate change and the severe snow storm in Texas that shut down the power for Texas for a long period of time. We thought about what we could do to avoid this problem and how climate change is affecting the power grid, and we realized that before we moved to a different state we should focus on New Mexico to understand the power grid as a whole and not just one incident. The team researched the power grid, the different types of power plants, and their different working conditions. For the purpose of our project, we looked more into renewable energy (wind and solar).

Climate change is a problem and to change that we are starting with the power grid. The power grid affects us all by the constant use of power in all buildings and homes around the world. We wanted to include the aspect of climate to the power grid to think about real world issues to do with climate change; we focused on the overall temperature of the earth (as it has the impact of the rest of the global climate). The temperature and how it impacts the supply and demand of the power grid. How, when you have higher temperatures, it is more likely to increase the demand of the power. We looked into the different sources and what it meant for each source of energy in the power grid.

Figure 1: U.S Average Residential Air-conditioning Expenditures by Climate Region, 2015



A Graph of the different climates in the United States and there demand for air-conditioners
https://www.eia.gov/todayinenergy/images/2018.07.23/main.png

Method

At the beginning of our project, we did not have a clue on what to do for our project. We are seniors this year, and wanted to go out with a bang. We each decided to research things we were interested in and then decide from there what project we should go with. It started with climate change. Climate change is a major issue in our science community, so we started researching different ways that humans are contributing to climate change, and a major one is power plants. Power plants contribute to climate change because of the use of fossil fuels.

More specifically, we have looked into different programs that showcase the climate in the future if we continue this way. The earth simulator replicates the earth and the temperatures it can help us understand what we can do in the feature to help lower the risk of the rising temperatures. We

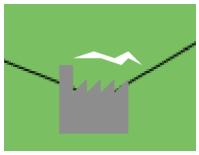
have also looked through the eia.gov website for statistics of the demand across the United States. Next, we took a look at graphs that showed supply and demand of AC usage and took the data and applied it to our code. After, we applied it to the understanding of our project and we started on the model for our code. We have showcased the most accurate representation of the power grid (a home model) through the NetLogo Program. We also have the element of temperature and the patches that turn different colors due to the temperature degrees. After working on our code we worked on gathering information from the model. We tested the amount of energy that is put out and what the temperature increase does to the energy for our results. After deciding what to do, we all got together and completed online research. We tried to contact PNM on our own to get a mentor or an expert to help us understand the power grid; however, we were unsuccessful on our own. After many failed attempts to contact PNM, we talked to our sponsor teachers and they helped us find a mentor who works for PNM. We met with our mentor every other week, and he helped us figure out what we needed to do. A few of us would meet on Thursdays to check out books from the library and work on the code. On a few Wednesdays, our main coder, Nancy, would work with Mary Sagartz on the code during code breaks. We continued to improve our code, read our books, and researched online to continue to understand the power grid and climate change.

Code

This year's code relies heavily on a simple power grid model on NetLogo. At first we had wanted to use the computer language Processing to get our simulation; however, the team later learned that using NetLogo would be a better fit for this project. The code will show the electricity coming from the generator and walk its way down to the house; the need for a simple path is to have a simplified version of a power grid and how it is affected by temperature. The code is meant to show the connection between energy and the Earth's rising temperature. The code contains a Setup and a Go button, a temperature slider, and a "number of electricity (current)" slider. When the setup button is clicked the turtles for the power grid are created, the temperature is set at 50°F, and the electricity slider is set at one hundred. When the go button is pressed, the electrics are only created when the user moves the slider. As the temperature slider changes (also by the user's input), the step size of the electrics change only when they arrive at a new destination (turtle). The program stops when all of the electrics die at the house. For visual aid, the patches change color when the temperature increases or decreases. As temperature increases, then the demand for electricity increases and as temperature decreases, then the demand for it is lowered. Nancy, the main coder, attended a few code breaks and worked with Mary to get the electricity to walk down the power lines in one direction and to die at the house. With Mary's help, Nancy was able to have her electricity walk down the path and die at the house without turning back. The electricity's step speed changes as the temperature increases. This is to model as temperatures increase then the demand for more electricity increases.

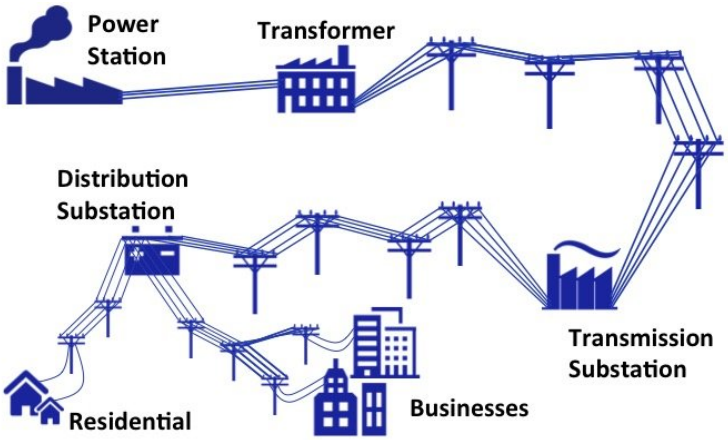
Code Key

In order of appearance:

Turtle Image	Meaning
	Power Station
	Transformer
	Transmission Substation
	Distribution Substation
	House
	Current

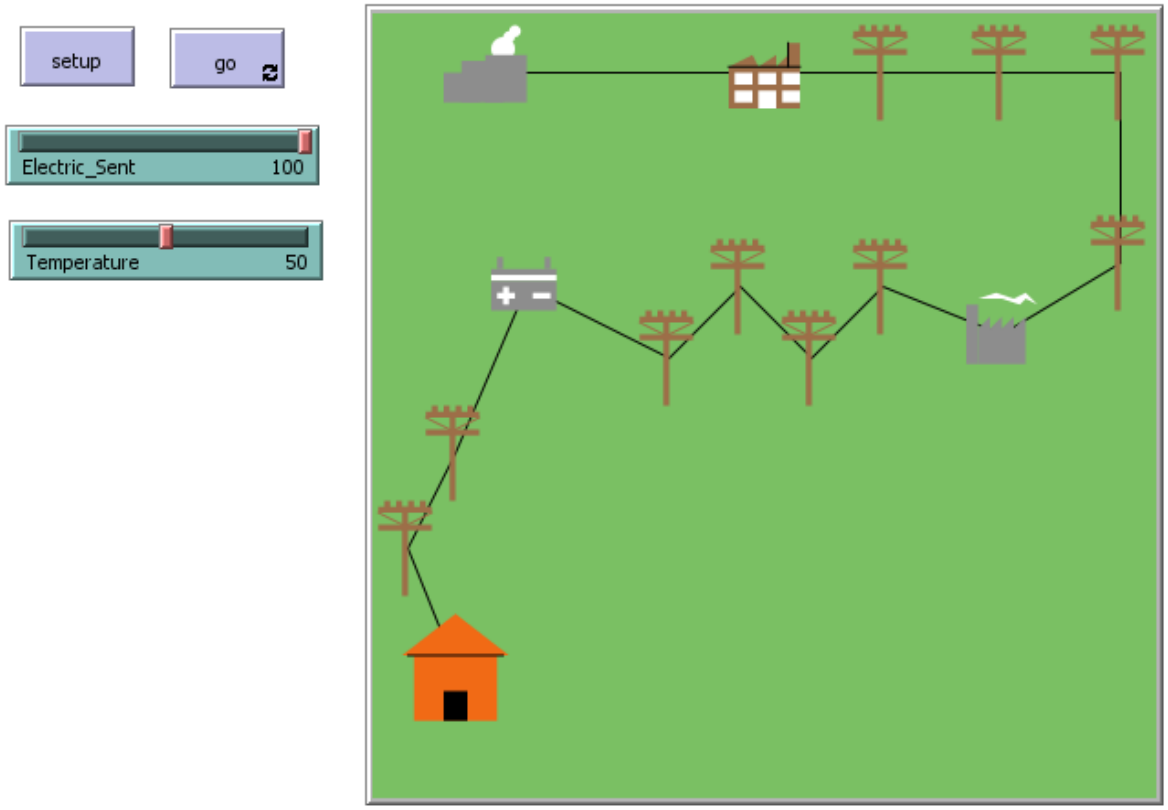
Interface

Figure 2: Power Grid Representation

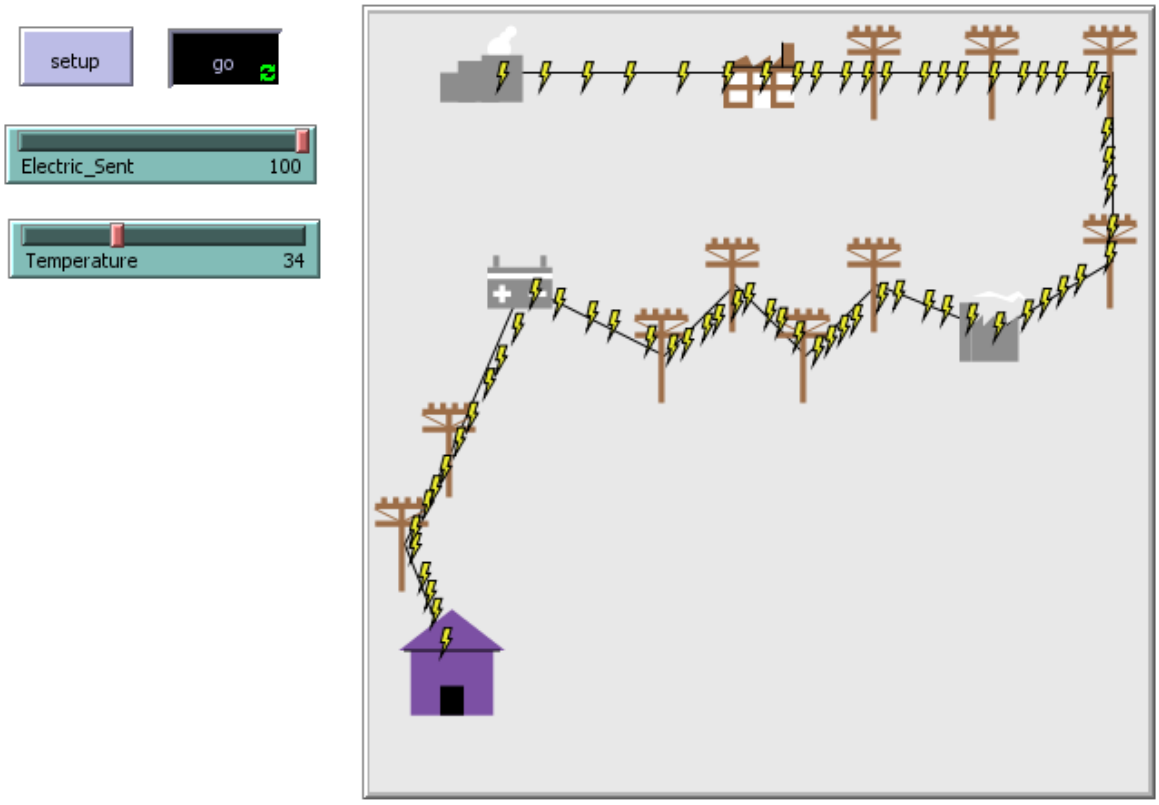


Model for the code interface (businesses were eliminated to keep simplicity)
https://www.researchgate.net/figure/Power-Grid-Architecture_fig3_312562428

Setup with 50°F and zero electrics/current:



Go with 34°F and one hundred electrics:



Code

```
;Help Gathered from CodeBreak Mary Sagartz
;Trying new code
globals [Visit-list electrics-to-create]

breed [generator generators]
breed [transformer transformers]
breed [transmission transmissions]
breed [pole1 poles1]
breed [pole2 poles2]
breed [pole3 poles3]
breed [pole4 poles4]
breed [pole5 poles5]
breed [pole6 poles6]
breed [pole7 poles7]
breed [pole8 poles8]
breed [pole9 poles9]
breed [pole10 poles10]
breed [distribution distributions]
breed [house houses]
breed [electric electrics]

electric-own [ where-to-list current-destination xdest ydest step-size
]  ;location ]


to setup
 clear-all

 set electrics-to-create electric_sent
 set Visit-list [ [0 14] [5 14] [10 14] [15 14] [15 6] [10 3] [5 5] [2
2] [-1 5] [-4 2] [-10 5] [-13 -2] [-15 -6] [-13 -11] ];; in order of
places the electrics will go

 show first Visit-list

;; temp = 50

 ask patches [set pcolor 56]

 ;; Power station
  create-generator 1 [
```

```
    set shape "power"
    set color grey
    set size 5
    set xcor -12
    set ycor 14
  ]
 ;; transformer
   create-transformer 1 [
    set shape "transformer"
    set color brown
    set size 5
    set xcor 0
    set ycor 14
  ]
 ;; pole for energy transfer
   create-pole1 1[
    set shape "pole"
    set color brown
    set size 5
    set xcor 5
    set ycor 14
  ]
  create-pole2 1[
    set shape "pole"
    set color brown
    set size 5
    set xcor 10
    set ycor 14
  ]
  create-pole3 1[
    set shape "pole"
    set color brown
    set size 5
    set xcor 15
    set ycor 14
  ]
  create-pole4 1[
    set shape "pole"
    set color brown
    set size 5
    set xcor 15
    set ycor 6
```

```
]
create-pole5 1[
  set shape "pole"
  set color brown
  set size 5
  set xcor 5
  set ycor 5
]
create-pole6 1[
  set shape "pole"
  set color brown
  set size 5
  set xcor 2
  set ycor 2
]
create-pole7 1[
  set shape "pole"
  set color brown
  set size 5
  set xcor -1
  set ycor 5
]
 create-pole8 1[
  set shape "pole"
  set color brown
  set size 5
  set xcor -4
  set ycor 2
]
 create-pole9 1[
  set shape "pole"
  set color brown
  set size 5
  set xcor -13
  set ycor -2
]
 create-pole10 1[
  set shape "pole"
  set color brown
  set size 5
  set xcor -15
  set ycor -6
```

```
 ]
;; Transmission substation
 create-transmission 1[
   set shape "transmission"
   set color grey
   set size 5
   set xcor 10
   set ycor 3
 ]
;; Distribution Substation
 create-distribution 1[
   set shape "distribution"
   set color grey
   set size 5
   set xcor -10
   set ycor 5
 ]
;; House
 create-house 1 [
   set shape "house"
   set size 5
   set xcor -13
   set ycor -11
 ]
 ;; connect the electric distribution places by drawing a line
 Connect-distribution
;;Now CO2
;;Temperature
 set Temperature 50
 reset-ticks
end

to go

 ask electric [
   forward step-size
;    show "going forward... I'm at...I'm going to"
;    show xcor
;    show ycor
;    show xdest
;    show ydest
```

```
   if ( abs (xcor - xdest) < .5) and (abs (ycor - ydest) < .5) [  ;;;
If the turtles coordinates are less than 1/2 a patch away, get a new
destination
    get-new-destination
   ]
 ]
;  show "electrics-to-create AND (remainder ticks 10 = 0)"
;  show electrics-to-create
;  show (remainder ticks 10 = 0)

 if (electrics-to-create > 0) and (remainder ticks 10 = 0) [   ;;;
Create new electrics every 10 ticks until done
    make-new-electric
 ]

;  show "turtle count"  show count turtles

 if count turtles <= 15 [stop]    ;;; If all the electric turtles are
gone, stop the program

 Temp

 tick
;; help from Codebreak Mary
end

to make-new-electric
   create-electric 1 [
;     show "New electric"
      set electrics-to-create (electrics-to-create - 1)
      set where-to-list Visit-list   ;list of poles/transformers/house
to visit
      set xcor -12                   ;(x, y) of generator, all
electrics start at the generator
      set ycor 14
      set size 3
      set shape "electricbolt"       ; shape of a lightening bolt
      get-new-destination            ; calculate a destination for the
electric
   ]
end
```

```
;;; The get-new-destination (current-destination) is grabbed from the
front of the where-to-list
;;; Then that destination is removed from the where-to-list.
;;; The step size is calculated from where the electric IS and the
current-destination.
;;;      When the electric gets to the new destination, you call the
routine again to assign the next place to go
;;;      When the Where-to-list is null, the electric can be deleted
;;; The electric will move forward by step-size.
;;; Heading set by current-destination
;;;
to get-new-destination

 ;    show "-----I'm in get-new-destination"
;    show "where-to-list"
;    show where-to-list

   If empty? where-to-list [ die ]                    ; If the
where-to-list is empty, the electrics die
   set current-destination first where-to-list        ; grab first
place to visit
   set where-to-list but-first where-to-list          ; remove the
first coordinate pair off the where-to-list

;    show "current-destination"
;    show current-destination

   set xdest first current-destination                ; First number
of current-destination is the x coordinate
   set ydest last current-destination                 ; Last number of
current-destination is the y coordinate

;    show "the (x,y) coordinates AND distancexy"
;    show xdest
;    show ydest
;    show abs ( distancexy xdest ydest)
;    show (102 - Temperature)


   ; calculate the step size. It is the distance divided by the
temperature, with 2 places after the decimal
```

```
   set step-size precision (((distancexy xdest ydest) / (102 -
Temperature))) 2

   show "step-size"
   show step-size

   facexy xdest ydest                                ;;; face the
correct way
;    show "-----Leaving get-new-destination"

end

to Connect-distribution          ;;; one electric will draw a line
between distribution points
 create-electric 1 [
   set where-to-list Visit-list   ;list of poles/transformers/house to
visit
   set xcor -12                   ;(x, y) of generator, all electrics
start at the generator
   set ycor 14
   set color black
   pendown
 ]

 ask electric [
   Repeat length Visit-list [                          ; how many
connection lines to draw
     set current-destination first where-to-list       ; grab first
place to visit
     set where-to-list but-first where-to-list         ;remove from
list
     setxy (first current-destination) (last current-destination)  ;;;
grab the (x, y) coordinates from current-destination
   ]
   die
 ]
end

to Temp
 ask patches [
   if Temperature >= 81 = True [set pcolor 15]
   if Temperature >= 60 = True and Temperature < 81 [set pcolor 26]
```

```
    if Temperature >= 50 = True and Temperature < 60  [set pcolor 56]
    if Temperature >= 30 = True and Temperature < 46  [set pcolor 9]
    if Temperature < 0 = True [set pcolor white]
  ]
end
```

Results

Ticks Between the Number of Energy Turtles and Temperature Increase

						Energy					
Temperature (°F)	**1**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
5	1224	1314	1414	1514	1614	1614	1714	1814	2014	2114	2114
10	1162	1252	1352	1452	1552	1652	1752	1852	1952	2052	2152
20	1048	1138	1238	1338	1438	1538	1638	1738	1838	1938	2038
30	907	997	1097	1197	1297	1397	1497	1597	1697	1797	1897
40	794	884	984	1084	1184	1284	1384	1484	1584	1684	1784
50	672	762	862	962	1062	1162	1262	1362	1462	1562	1662
60	536	626	726	826	926	1029	1126	1226	1326	1426	1526
70	410	500	600	700	800	900	1000	1100	1200	1300	1400
80	282	372	472	572	672	772	872	972	1072	1172	1272
90	158	248	348	448	548	648	784	848	948	1048	1148
100	28	118	218	318	418	518	618	718	818	918	1018

Through tests, the team was able to learn how energy may travel through the power grid. Using a simple model, we ran the code where we had a specific amount of energy turtles with a certain degree (fahrenheit). From our results, we were able to learn that as the temperature goes up the ticks it takes to run the code become smaller. When comparing the ticks that it took for the code to run with one energy versus ten energys at a set temperature, the ticks only had a difference of one hundred. When the ticks were 1,224 for one energy at 5° fahrenheit, the ticks were 1,314 for ten energies at 5° fahrenheit.

Conclusion

Throughout books, videos, articles, and talking with our mentor we are able to understand how climate change is being affected by power plants. We have learned that power plants and climate change have a distribution cycle because power plants will use more power the higher the temperature; we are able to demonstrate how the power plants work and what we, as society, can do to help with climate change. We ran tests and demonstrated through a mathematical table how much power it takes through numbers to run power plants with temperatures rising; we now have a better understanding of how power plants work and how climate change impacts them.

Significant Achievement

Nancy Avila Do:

Although this is my last year doing Supercomputing Challenge, I feel that I was able to learn a lot. We were often behind or lost when it came to our project, but I was able to push through and do something that I never thought I would be able to do. I was able to make some great progress with my code even though I had a rough late start with it. I am glad that I was able to learn how to continue to rely on my team for help, and even though I was stressed with the amount of deadlines, I found ways to overcome those obstacles. I learned to ask for help when I believed that I could and should do everything on my own. Holding myself accountable during time apart last year, made me go back to my original habits where I thought I could do everything myself; however, I was able to learn once again that it was okay to rely on my teammates again and to speak up when something I was uncomfortable with was present. Another achievement that I was able to accomplish this year was my ability to think like a coder. My ability to problem solve and compute what I was imagining shone through as I worked on my model on NetLogo. Although I am not as familiar with NetLogo as I am with Python, I was able to make the simple part of my vision into a reality. Even though it is not a super impressive code, I am happy that I was able to do some parts of the model that I had hoped to do this second half of the year. I am glad that I was able to improve and prove to myself that I have the ability to do what I want as long as I put my mind to it.

Candis Canaday:

This year is my second year in Supercomputing Challenge. I am still quite a bit behind my teammates in coding, but I was able to understand a lot more than I was capable of at this time last year. Even with the ability to better help my teammates, it was still a difficult year when it came to meetings and communication. We were able to meet every Monday, but most of my team and I got jobs which severely limited the amount of time slots that would work out for everyone. My job was both a hindrance and an advantage when it came to Supercomputing. I work in one of the local libraries, so I was able to help my teammates find books that would help us out and point them in the direction of topics that might benefit our project. I also began to teach myself to code a bit more; I had only been able to pick up on the basics of what my teammates were working on so teaching myself with books and online resources has helped me to better understand what is happening in our code. It has been a very eventful year, and I am grateful for my teammates who help me with things related and unrelated to our project.

Gwenevere Caouette:

My most significant achievement this year is the fact that I stepped out of my comfort zone. For years, I have done the code and this year I was able to admit defeat and couldn't do the code properly. I was able to ask for help, which is hard for me to do because of my stubbornness. I am happy to have teammates that are willing to step in and take over as I took over their own parts. I'm so proud of my team for the last few years, and as I go off to college I am glad we are going together. We were able to use thelirbary for resources, which we have never done before too. I am happy that we were able to work together and gather research outside of online articles.

Kyreen White:

This year was very difficult; with the craziness of senior year getting to all of us in a way we could've never imagined. We were all focusing on other things than the project which made it hard to get our project to where we would've wanted it to be. We had a hard time picking a topic and agreeing on an idea. I would say my most significant achievement this year was helping the team stay on task during meetings and proposing next step plans. We also gathered books and read through them to improve our understanding of climate change and the power grid. Nancy and I picked books to read and get more information for the rest of the team; which is also a great achievement because last year it was very difficult to get books and to distribute them to other teammates. I am also taking AP Computer Science Principles (as my math class) which has helped with my understanding of coding and I have been a great addition to the team in that way. I'm happy that even with all of our missed trials that we can overcome it and still finish the project strong this year.

Acknowledgements

We acknowledge the following people:

Karen Glennon

Mrs. Glennon has worked with us since we were in middle school. Although not all of us have been in Challenge for a very long time, she has always been someone of huge impact and importance in our lives. Her guidance and support had helped us grow into better individuals and teammates. Without her constant encouragement and guidance, we would not have been able to get this far. It was and is an honor to have Mrs. Glennon as our sponsor teacher.

Chris Hoppe

Thank you so much Mr. Hoppe for giving us the advice to get to the point we are at right now. For giving us great advice about our program and adding the different components. Thank you so much for taking time out of your day to evaluate us and help us with our progress of the project.

Jack Ingalls

We thank Jack Ingalls for his help as our mentor. Although we did not get to work with each other for a very long time, we have learned a lot from him in such a short time. We are glad that we were able to work with someone who was able to lead us in the right direction and help us with the explanation of our research and code. The team acknowledges the fact that we could not have done it without Mr. Ingalls' help. We are lucky to have had a mentor who is also a Challenge alumni and who also understands what it is we needed to do to be successful this year.

Maximo Lazo

Mr. Lazo was kind enough to be a judge for our evaluations in February. His feedback was a great help and motivated us to better our project. He asked questions to lead us in the direction of our next step for our code, and we thank him for his suggestions and time.

Sharee Lunsford

Ms. Lunsford has been our teacher sponsor since sixth grade. We have grown together throughout the years and have been one of our greatest supporters. With her help in editing our papers, taking us to events, or being our audience for practicing our presentation; she is able to give us the best feedback and further ourselves in challenges. Thank you so much for your support throughout the years and encouraging us.

Patty Mayer

We have known Mrs. Patty since we were all in middle school, and she has always helped us with our problems and asked questions that judges might ask during evaluations or finals. We would like to thank Patty Mayer for always being there to look over our papers and for helping us through roadblocks that we went through during our project this year. Also, for always being there to make us laugh and lighten the mood when we were stressed about the next deadline for the project. Thank you so much again!

Davy Torres

The team thanks Davy Torres for taking time out of his day to come and evaluate our project. His advice and guidance for our project really helped us move forward with what we could improve on with our code. His questions and responses were really helpful when deciding what we needed to do to be successful with our code. Thank you.

Mary Sagartz

We thank Mary for all of her help when we struggled with our code. She helped us learn and explain all aspects of the coding that she was able to help us with. Without her help, it would have been really difficult to get this much progress on the code. She was able to understand what we wanted even if our explanations were not as well phrased, and she was willing to work with us outside of code break days and hours. The team is glad to have the opportunity to work with Mary.

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Jack Ingalls: PNM Distribution Standards Jack.Ingalls@pnm.com

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