Sparks vs. Bolts: An Exploration of the Environmental Efficacy of Electric and Gasoline Vehicles

Team 25, The Auto Club

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Final Report

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Executive Summary

Throughout the decades, new technologies have arisen to solve some of the greatest environmental ills plaguing society. One such technology is the electric vehicle, which in recent years has been proffered as a more suitable substitute for conventional gasoline vehicles in terms of environmental effect and overall efficiency. Many provinces in countries around the world, including the United States, have proposed legislation necessitating the eventual ban of conventional gasoline vehicles in favor of electric or hybrid replacements. Concurrently, scientists and conservationists alike have attempted to evaluate the benefits or drawbacks of electric vehicles in comparison to gasoline cars. These evaluations range from the affordability of both vehicles, their functionality, and, perhaps most importantly, their respective carbon footprints. Likewise, we have decided to research both types of vehicles and explore their various facets.

Introduction

Problem Statement

The debate surrounding the efficiency of electric vehicles, as opposed to conventional gasoline vehicles, is continuous. It is often thought that electric vehicles contribute less to atmospheric carbon emissions, but when the production and actual usage of both types of vehicles are considered, does the use of electric cars actually result in a smaller carbon footprint? At what point is the use of electric cars more beneficial than that of normal vehicles? These are the issues we intend to explore with this project. By compiling information and creating a well-functioning model that is analogous to and supported by research, we expect to find that, overall, electric cars have a smaller carbon footprint (and impact on the environment) than conventional gasoline vehicles.

Background Research

The four vehicles with which we narrowed the scope of our research are the 2022 Tesla Model 3, the 2022 Mazda 3, the 2022 Chevrolet Bolt EV, and the 2022 Chevrolet Spark. The selection of these vehicles was based on similarities in their physical appearances. We believed this contributed to their comparability. The unit with which we measured carbonic influence is the CO2e. CO2e is the carbon dioxide equivalent of a vehicle, and it refers to the environmental contribution of a vehicle regarding carbon dioxide and greenhouse gas emissions. Noting the number of each vehicle sold in 2022 will allow us to adjust the number of vehicles in our model to parallel real-world scenarios (see Table 1).

Vehicle	**CO2 Emissions from Production Stage (g CO2e/km)**	**CO2 Emissions from Usage Stage (g CO2e/km)**	**Number of Vehicles in the U.S.**
2022 Tesla Model 3	62	304	156,357
2022 Chevrolet Bolt EV	-	57	22015
2022 Mazda 3	-	139	25781
2022 Chevrolet Spark	-	165	13708

Table 1. A Table Displaying Compiled Research About Electric and Gasoline Vehicles

In 2022, 156,357 Tesla Model 3 vehicles were sold. [13] Generally, scientists have discovered that the manufacturing impact of a Tesla is the same as that of a standard full–size combustion car. The batteries in electric vehicles (such as Tesla vehicles) increase carbon emissions during manufacturing by an average of 15%. [5] Nevertheless, Tesla also recycles batteries, which contributes to the recovery of nearly 70% of the vehicle's carbon potential. The carbon dioxide emissions during the raw material acquisition stage of the development process of the Tesla Model 3 are 62 g CO2e/km. The emissions during the production stage are 10 g CO2e/km. The emissions during the usage stage of the Tesla Model 3 are 304 g CO2e/km. [4]

Regarding the Mazda 3, 25,781 vehicles of this model were sold in 2022. [14] The carbon dioxide emissions for the automatic variant of the Mazda 3 range from 138-140 g CO2e/km. [2]

For the 2022 Chevrolet Bolt EV, 22,015 vehicles were sold in 2022. Approximately 57 grams of CO2e are emitted per kilometer driven. [6]

For the Chevrolet Spark, 13,708 vehicles were sold in 2022. [15] Approximately 165 g/km of CO2e are emitted during the usage stage. [1]

Computational Model

Selection

We chose to use NetLogo, an agent-based language, to program our model from scratch. As we progress in our experiment, we intend to evaluate the use of NetLogo versus Python and R (the latter of which are more stochastic ways of exhibiting data) in solving our problem. Our model incorporates numerous agents, representing cars. Each vehicle has a lifespan, an annual carbon footprint, and an initial carbon footprint (which entails the carbon footprint the vehicle has from the raw acquisition and production stages), among other specifications. The intended purpose of our model is to display the carbon emissions of various brands of cars (electric and conventional) and track these emissions as time elapses.

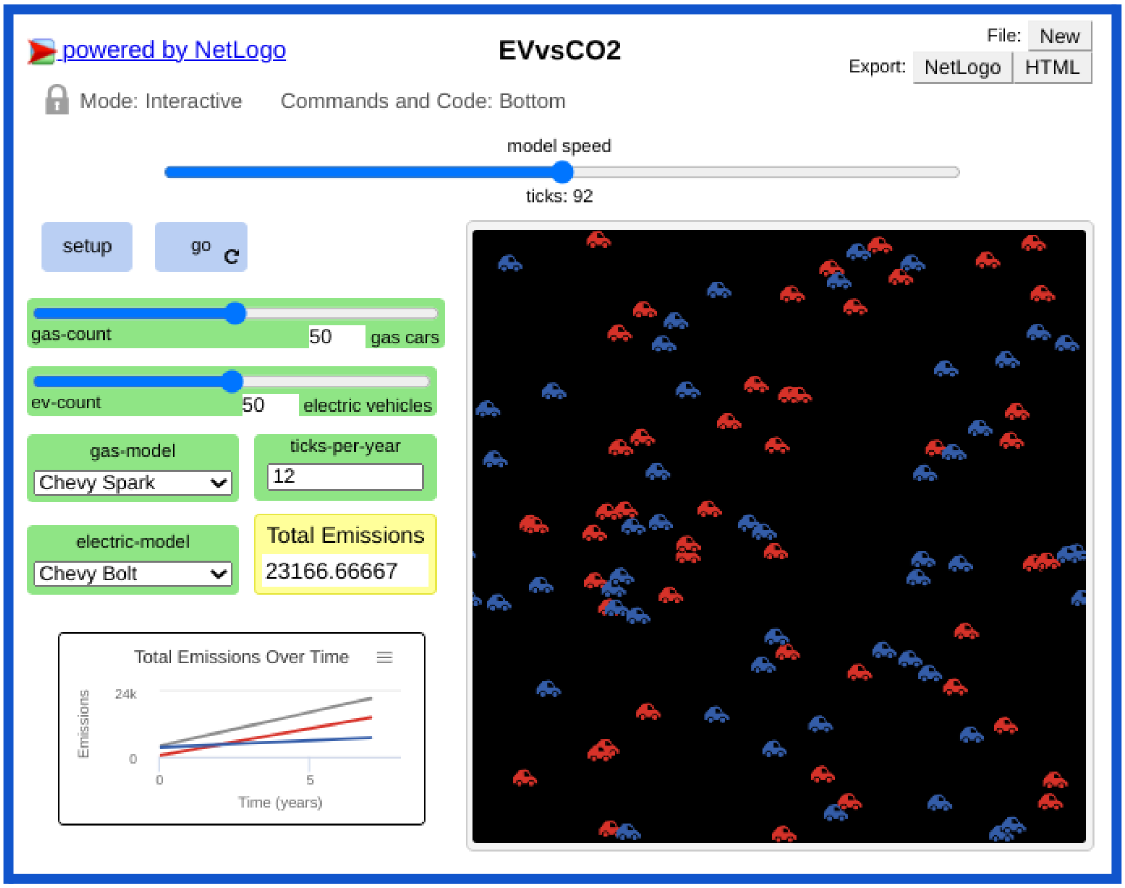

Figure 1. An Image Capture of our Sparks vs. Bolts Model

As part of our project, our mentor instructed us in the use of Python, which we considered another possible computational method to implement as time progresses. We used the online platform Binder to convert our pre-existing Github repository into a collection of interactive notebooks for educational purposes. [12] Binder allows our work to be replicable. Furthermore, our exploration of Binder enabled us to learn about Python through “hello.py.”

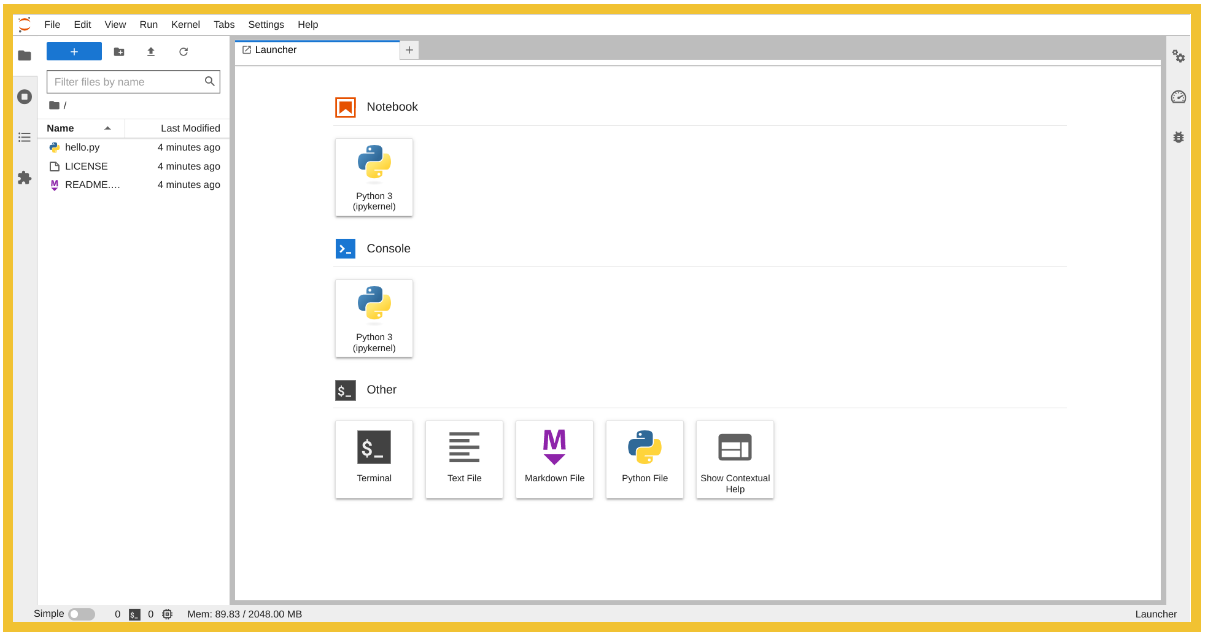

Figure 2. An Image Capture of our Binder Homepage

Modifications

The initial version of our model included a slider entitled "gas-count," which measured the number of gasoline-powered vehicles in the model interface (see Figure 1). It also included a slider called "ev-count," which measures the number of electric vehicles present in the environment. The user could navigate the "gas-model" and "electric-model" drop-down menus, which contained the four vehicles (two electric and two conventional gasoline vehicles) upon which our study is based. Later, we updated our model to include a "ticks-per-year" section; this determines the simulation time in days, months, or years. Upon compiling information about the emissions of our selected vehicles, we were able to incorporate a "Total Emissions" tracker. Our determined unit for measuring the effect of gasoline and electric vehicles on the environment (and for understanding the "Total Emissions" portion of our project) is the CO2e, or carbon dioxide equivalent. It is essential to our project. Consequently, we included a graph entitled "Total Emissions Over Time" to supplement the tracker and delineate the emissions from electric vehicles (as indicated by the blue line), gasoline vehicles (as indicated by the red line), and emissions from the overall presence of both vehicle types (as shown by the gray line).

Visualization

As NetLogo is an agent-based software, our model utilizes "turtles" that, as it pertains to our project, are shaped like cars (see Figure 3). When the user presses "Setup," the model generates a specified number of gasoline and electric vehicles. This amount is determined by the user through the manipulation of sliders on the left-hand side of the model. While the red turtles represent gasoline-powered vehicles, the blue ones correlate with the presence of electric vehicles in the United States. For this project, the red cars are indicative of the 2022 Mazda 3 and 2022 Chevrolet Spark. The blue cars represent the 2022 Tesla Model 3 and 2022 Chevrolet Bolt EV, the specific electric vehicles scrutinized in this experiment.

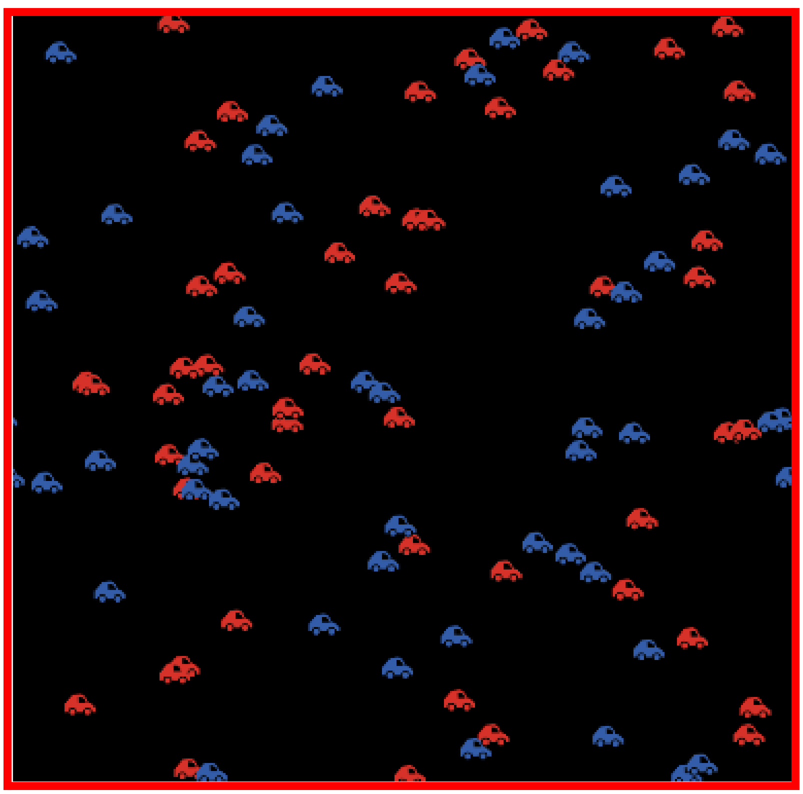

Figure 3. An Image Capture of the Environment of our Sparks vs. Bolts Model

As time progresses, the number of "Total Emissions" fluctuates (namely, it increases) and NetLogo generates a graph reflective of the environmental occurrences. This graph will potentially allow us to answer the question, "At what point is the use of electric cars more beneficial than that of normal vehicles?" Eventually, the vehicles "gray" out (this does not happen simultaneously, but successively). This represents the exhaustion of the grayed-out vehicle and its overall depletion as a consequence of reaching the end of its lifespan (see Figure 4). Generally, we observed that the red vehicles (the gasoline-powered ones) were the first to lose their color.

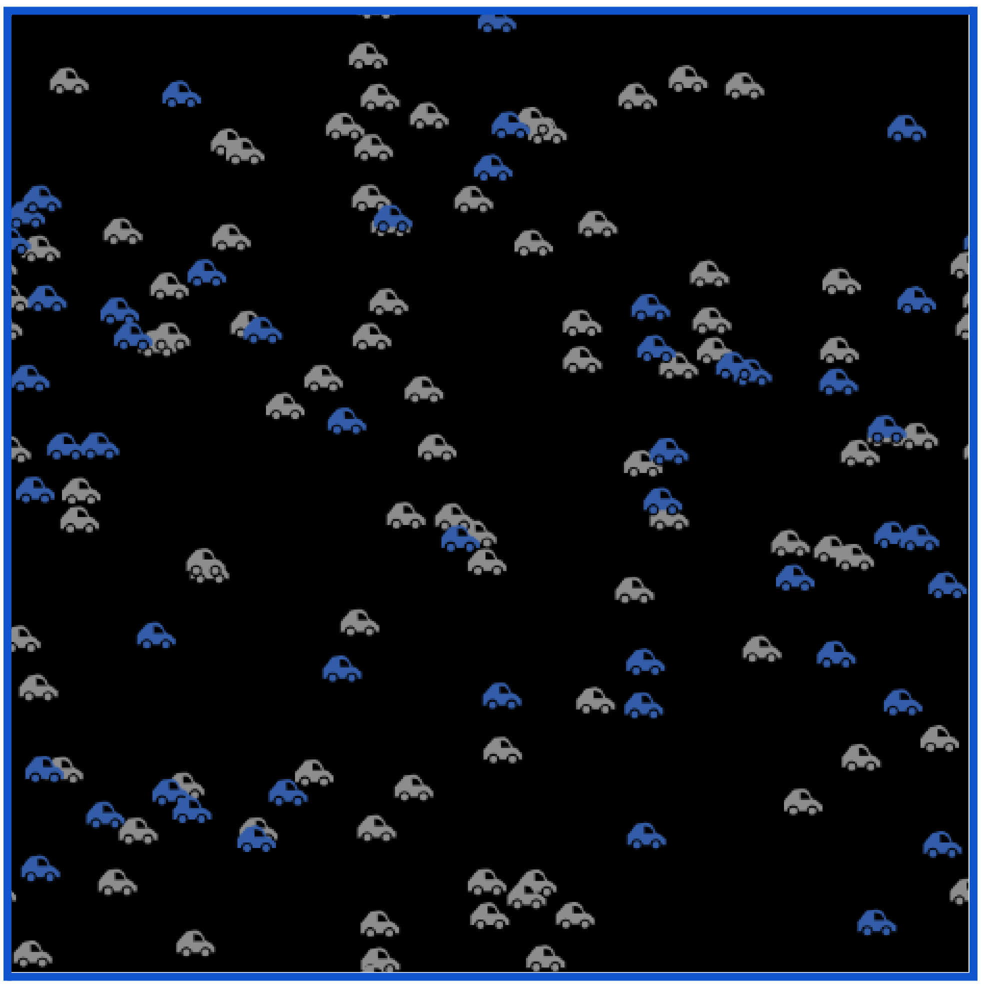

Figure 4. An Image Capture of the "Gray" Vehicles in our Sparks vs. Bolts Model

Limitations

The limitations we encountered in this project regarded a scarcity of research pertinent to our model. We encountered some obstacles whilst researching information about the emissions from the production processes of the 2022 Mazda 3, 2022 Chevrolet Spark, and 2022 Chevrolet Bolt EV. While there was a plethora of information about the emissions produced during the production and raw material acquisition stages of the Tesla Model 3, this information was not readily available for the three other vehicles upon which we chose to base our model.

Another limitation involved the apparatuses by which we completed our coding. When we first began writing the code for our model, we lacked access to computers and used Chromebooks to update our program. This lack of availability and dependency on Chromebooks prevented us from utilizing some of NetLogo's more pertinent softwares, such as BehaviorSpace. Our coding platform was limited to NetLogo Web, which came with its own predicaments. An internet connection is needed for NetLogo Web, whereas one is unnecessary for the NetLogo desktop application. Fortunately, although most of our code was written using Chromebooks, we eventually came into possession of laptops for easier programming.

Problem-Solving Method

Verification

We configured our model to be as realistic and accurate to the real world as possible. Naturally, the composition and creation process of a vehicle can influence its greenhouse gas emissions and overall impact on the environment. Our model reflects real-world statistics about our selected vehicles and their corresponding lifespans, emissions, and prevalence in the United States. To verify the results of our model in the future, we intend to use NetLogo's

BehaviorSpace addendum. However, our current dearth of research would render the use of this platform ineffective.

Corroboration

Our results are corroborated by the information we compiled from various studies during our research. The resources we accessed were verified and reliable, and the data we inputted into our model reflects accurate findings from these sources. Ultimately, the outcome of our model will be corroborated by real-world trends.

Conclusion

Results

Thus far, we are yet to run official tests with our model. With NetLogo, we have created sliders and global variables. Each vehicle has different variables: lifespan, age (as the program progresses), carbon emissions from the production process, and annual carbon emissions (from the actual usage of the car). The model begins with the total emissions at zero. The user can alter the amount of gasoline or electric cars present in the environment. When the user presses "Setup," the model adds the emissions from the production process to the emissions from car usage. When the user presses "Go," the model displays how much carbon is released during the lifetime of the vehicles.

Discussion

We hypothesized that, overall, electric vehicles will have less of an impact on the environment in terms of carbon dioxide emissions. Once we have finished inputting statistically accurate information into our model, we will run experiments and be able to determine which type of vehicle is most efficient and environmentally beneficial.

Future Work

While we managed to create a model that reflects data compiled from research, the incompletion of this research prevented us from incorporating the carbon emissions from production for the 2022 Chevrolet Bolt EV, the 2022 Mazda 3, and the 2022 Chevrolet Spark. We want to find more information about these vehicles and remove the incongruities present in our work and data thus far.

We also intend to add complexity to this model and overall project by exploring other aspects of vehicle ownership, such as the range of electric and conventional gasoline vehicles, their respective capabilities, their prices, and the proximity of charging stations for both types of vehicles. By evaluating more facets of electric and gasoline vehicles and diversifying the scope of our experiment, we hope to achieve a more holistic view of the debate surrounding these cars.

Acknowledgments

Our progress in this year's Supercomputing Challenge would not have been possible without help from various individuals and organizations.

We thank the nonprofit organization Justice Code for arranging meeting times with our sponsors and mentor and providing us with digital and physical meeting spaces to collaborate.

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We appreciate our mentor, Daniel Fuka, whose expertise in biological systems and engineering has contributed significantly to our project.

We thank Uri Wilensky, Northwestern University, and NetLogo for the coding language we used to create our model.

Finally, we thank the judges, scientists, and individuals associated with the Supercomputing Challenge for their input throughout this project (through Code Breaks and regular e-mail correspondence) and their cultivation of a space in which scientific curiosity thrives.

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Appendix: Code

```
;; chevy bolt
;; chevy spark
;; tesla model 3
;; 2022 mazda3

extensions [array]

globals
[
  car-size
  total-emissions
  total-emissions-gas
  total-emissions-ev

  cars-remaining
]

turtles-own
[
      lifespan
  age
  production-carbon
  annual-carbon
  type-of-car
]
```

```
to setup
  clear-output
  setup-globals
  setup-experiment
end


to setup-globals
  set car-size 4
  set total-emissions 0
  set total-emissions-gas 0
  set total-emissions-ev 0

  set cars-remaining ( gas-count + ev-count )
end


to setup-experiment
  clear-patches
  clear-turtles
  clear-all-plots
  clear-ticks

  setup-cars

  set-default-shape turtles "car"

  reset-ticks
end


to setup-cars
```

```
; first item is initial co2 prod
; second item is annual co2 prod
; third item is lifespan in years

; using 14,263 miles driven per year

let bolt-data array:from-list [0 1312 8]
; Chevy plans to make their factories carbon neutral
; approx 1312 kg per year | 92 grams of CO2 per mile
; 8 years

let spark-data array:from-list [0 3837 12]
; Chevy plans to make their factories carbon neutral
; approx 3837 kg per year | 269 grams of C02 per mile
; ranges from 10 to 14 years | 150,000 to 200,000 miles

let tesla-data array:from-list [9200 1859 28]
; range between 2400 kg and 16,000 kg
; approx 1859 kg per year | 0.81 kg per 10 km
; between 21 and 35 years of operation

let mazda-data array:from-list [0 3191 18]
; Mazda plans to make their factories carbon neutral
; approx 3191 kg per year | 139 kg per km
; ranges from 14 to 21 years | 200,000 to 300,000 miles

    create-turtles (gas-count)
[
```

```
    setxy random-xcor random-ycor         ; randomize turtle locations
    set size car-size                              ; easier to see
    set color red
    set age 0
    set type-of-car "gas"
    ;;
    set heading (round (random 360 / 90) ) * 90

    ;; give each car data
    ifelse gas-model = "Chevy Spark"
    [
      set production-carbon array:item spark-data 0
      set annual-carbon array:item spark-data 1
      set lifespan ( (array:item spark-data (2)) * ticks-per-year )
    ]
    [
      set production-carbon array:item mazda-data 0
      set annual-carbon array:item mazda-data 1
      set lifespan ( (array:item mazda-data (2)) * ticks-per-year )
    ]



    set total-emissions (total-emissions + production-carbon)
    set total-emissions-gas (total-emissions-gas + production-carbon)

  ]
  create-turtles (ev-count)
  [
    setxy random-xcor random-ycor         ; randomize turtle locations
```

```
    set size car-size                            ; easier to see\
    set color blue
    set age 0
    set type-of-car "ev"

    set heading (round (random 360 / 90) ) * 90



    ifelse electric-model = "Chevy Bolt"
    [
      set production-carbon array:item bolt-data 0
      set annual-carbon array:item bolt-data 1
      set lifespan ( (array:item bolt-data (2)) * ticks-per-year )
    ]
    [
      set production-carbon array:item tesla-data 0
      set annual-carbon array:item tesla-data 1
      set lifespan ( (array:item tesla-data (2)) * ticks-per-year )
    ]

    set total-emissions (total-emissions + production-carbon)
    set total-emissions-ev (total-emissions-ev + production-carbon)
  ]

end

to go
  set cars-remaining ( gas-count + ev-count )
```

```
  ask turtles [
    ifelse age >= lifespan
    [
      set color gray
      set cars-remaining (cars-remaining - 1)
    ]
    [
      drive
    ]

  ]

  ifelse cars-remaining = 0
  [ stop ]
  [ tick ]

end



to drive  ;; turtle procedure
  ifelse random 10 < 5 ;; 50% chance to go for a drive
  [
    fd 5
    set age (age + 1)
  ]
  [
    ifelse random-float 2 > 1
    [ rt 90 ]
    [ rt -90]
```

```
        set age (age + 0.25)
  ]

  ifelse type-of-car = "gas"
  [
    set total-emissions-gas (total-emissions-gas + (annual-carbon /
ticks-per-year))
      ]
  [
    set total-emissions-ev (total-emissions-ev + (annual-carbon /
ticks-per-year))
  ]

  set total-emissions (total-emissions + (annual-carbon / ticks-per-year))
end
```