ECA-Effective Community Action model - Investigation on how collective changes can make a global impact.

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Abstract

Misinformation on climate change is rampant, malicious, and targeted to prevent collective action (Treen, 2020). Beyond the outright denials that it's happening, or the attempts to claim that climate change isn't due to human actions, assurances that climate change can be solved by individual actions can be just as counter productive (Levermann, 2019). Climate models are an excellent way to educate on climate change but most models focus either on individual's carbon footprints or on the scale of UN resolutions and collective governments' response to climate change (Sterman, 2013). Little to no models exist that bridge the gap between UN resolution and what the citizen can vote on at the ballot box. The ECA-Effective Community Action model is designed to address that need. It focuses on 6 core topics, travel, food, energy, residential and commercial, industry, and land use. Each topic has a number of anthropogenic sources of carbon dioxide that the user can change to see the effect on the global system. The goal of the model is to demonstrate in an engaging way how policies on the national and local level can have an impact on climate change. The model successfully models 44 anthropogenic carbon sources, and produces results within the expected range of temperature rise. However, the model is still lacking in key areas and additional research is needed to continue to improve the model.

Introduction

Climate change is a disaster in slow motion. It is already pushing forward the scale, intensity, and frequency of natural disasters at an alarming rate (Climate, 2023). Currently, 3.6 billion people live in high risk areas, and by 2030 climate change is expected to be responsible for the deaths of more than 250,000 people a year (Climate, 2023). Yet the link between anthropogenic carbon dioxide emissions and climate change was first established in 1896, and since then the data has only gotten more and more overwhelming that anthropogenic emissions cause climate change (NASA, 2018). Humanity saw this coming, but lacked the collective political willpower and regulatory tools to put a stop to it. However, it is becoming increasingly clear; if we don't put a stop to climate change, sooner or later it will put a stop to us.

Climate change's solution is simple but difficult; stop putting carbon dioxide into the atmosphere and climate change will stop accelerating (Is it too late, n.d.). Humanity would still have to contend with the damage that has already been done, but this would slow, if not stop an existential threat. It is the discussion on climate change that makes it a hard issue to tackle. Misinformation is rampant, malicious, and targeted to prevent collective action (Treen, 2020). Beyond the outright denials that it's happening, or the attempts to claim that climate change isn't due to human actions, assurances that climate change can be solved by individual actions can be just as counter productive (Levermann, 2019).

Climate simulations are an excellent method to communicate and educate on climate change (Sterman, 2013). A climate simulation simulates what will happen to the climate over time given certain inputs. Models like the C-Roads, and En-Roads track the climate on a global scale and are designed to be used with a model UN to demonstrate the potential effects UN resolutions could have on climate change (Sterman, 2013). On the other side of the scale there are climate simulations used to track an individual's carbon footprint. A concept created by oil companies to prevent effective action on climate change (Solnit, 2021). This creates a conundrum, the average citizen can't hold the United Nations accountable in the same way they could their own government. Yet little to no models exist that bridge the gap between UN resolution and what the citizen can vote on at the ballot box.

The ECA-Effective Community Action model is designed to address that need. It focuses on six core topics, travel, food, energy, residential and commercial, industry, and land use. Each topic has a number of anthropogenic sources of carbon dioxide that the user can change to see the effect on the global system. The goal of the model is to demonstrate in an engaging way how policies on the national and local level can have an impact on climate change.

Methods

The ECA-Effective Community Action model is programmed in Electron js. This is a framework that packages chromium with node js, allowing for a desktop app to be built in HTML, Javascript and CSS. The code ECA-Effective Community Action model was built to be intuitive and easy to modify and expand even for those without comprehensive computer science knowledge. To that end the majority of objects in the program are dictionaries, which are less efficient than arrays but allow the data to be called with meaningful terms instead of numbers.

The model tracks 44 anthropogenic sources of carbon dioxide. By default they are set to match the current level of emission as of 2023. When interacting with the model the user can increase or decrease each factor to see the effect it will have on the global temperature rise. For ease of use the model divides carbon dioxide emissions into six topics: travel, food, energy, residential and commercial, industry, and land use.

Figure 1 Screenshot of the main page ECA climate model. The figure shows the main menu with the 6 core topics.

On the main page the user can see the current world value of carbon dioxide emissions and the six main topics. On the topic pages the user is presented with a slider for the relevant sources of anthropogenic carbon tracked by the model and can change the value for the source using a slider input. On the results page the user can see the projected temperature rise given the values they modified over a span of a hundred years.

On a programming level the model has three main components. The UI, the data and the computation. The UI, or user interface is what the user sees. Processes involving the UI, like generating the menus, visuals, and buttons, are within the UI folder.

The data is where the data for the simulation is stored and formatted in a way the model can understand. It is stored within the data folder. The program is designed so if a collaborator wants to update, add or remove to the data they can do so here without having to edit anything else in the program.

The information on each source of anthropogenic carbon modeled by the program is split up by topic. Each topic has a file named [TopicName]Data.js. Wherein it contains a dictionary that holds the topic's information page and an array that contains the data on each source of anthropogenic carbon. Each source of anthropogenic carbon is modeled as a dictionary, where the title, possible value range, default value, and CO2 multiplier are stored. The data for these values was determined through a literature review and a justification and discussion of limitations for each carbon source can be found in its respective topic information page.

Figure 2 A screenshot of a then food topic data file for the ECA climate model. The screenshot displays how the data is stored and the keywords required to access the data from the dictionary .

```
src > TopicData > JS foodData.js > ...
import {TopicInfo} from "./topicInfo.js"

const FoodInfo = TopicInfo["Food"]
const Rice = {"Title": "Rice", "Range": {"Min": 0,"Max":200}, "Default":100,   "CO2Muitiplyer":2263410000/100}
const Shrimp = {"Title": "Farmed Shrimp", "Range": {"Min": 0,"Max":200}, "Default":100,   "CO2Muitiplyer":159894000/100}
const Goat = {"Title":"Goat","Range":{"Min": 0,"Max":200}, "Default":100,  "CO2Muitiplyer":20000000/100}
const Buffalo = {"Title":"Buffalo","Range":{"Min": 0,"Max":200}, "Default":100,  "CO2Muitiplyer":410000000/100}
const Sheep = {"Title":"Sheep","Range":{"Min": 0,"Max":200}, "Default":100,  "CO2Muitiplyer":450000000/100}
const Chicken = {"Title":"Chicken","Range":{"Min": 0,"Max":200}, "Default":100,  "CO2Muitiplyer":930000000/100}
const Pork = {"Title":"Pork","Range":{"Min": 0,"Max":200}, "Default":100,  "CO2Muitiplyer":1200000000/100}
const Beef = {"Title":"Beef","Range":{"Min": 0,"Max":200}, "Default":100,  "CO2Muitiplyer":4300000000/100}
const Milk  = {"Title":"Milk","Range":{"Min": 0,"Max":200}, "Default":100,  "CO2Muitiplyer":1600000000/100}
const Eggs = {"Title":"Eggs","Range":{"Min": 0,"Max":200}, "Default":100,  "CO2Muitiplyer":280000000/100}
const Cheese  = {"Title":"Cheese","Range":{"Min": 0,"Max":200}, "Default":100,  "CO2Muitiplyer":532080000/100}
const Chocolate  = {"Title": "Chocolate", "Range": {"Min": 0,"Max":200}, "Default": 100,  "CO2Muitiplyer": 235000000/100}
const Coffee  = {"Title": "Coffee", "Range": {"Min": 0,"Max":200}, "Default": 100,  "CO2Muitiplyer": 293190000/100}
const PalmOil  = {"Title": "Palm Oil", "Range": {"Min": 0,"Max":200}, "Default": 100,  "CO2Muitiplyer": 538740000/100}

const FoodPolicies = [Rice, Goat, Beef,Pork,Shrimp, Buffalo,Sheep, Chicken, Milk, Eggs,Cheese,Chocolate,Coffee, PalmOil]

var FoodData = { "TopicInfo": FoodInfo, "Policies" : FoodPolicies}
export {FoodData};
```

Finally there is the computation, which involves calculating the results displayed to the user on the results page. Files concerning computation can be found in the computation folder. To generate the temperature change in the results, the current value of each anthropogenic carbon source in the model is multiplied by its CO2 multiplier value. This calculates a value in tonnes. That number is then used to find the value of anthropogenic Co2 emissions that remain in the atmosphere using the equation:

$$anthropogenic\ \ CO2\ emitted\ \ *\ 4/9\ \ =\ \ CO2\ remaining\ in\ atmosphere$$

As only roughly 0.44 percent of anthropogenic carbon is released remains in the atmosphere, with the rest dissipating to the ocean or other stores (Carbon, n.d.).

This is then converted to tonnes per ppm using the equation:

$$CO2\ in\ Tonnes/(1000000000\ *\ 7.8)\ \ =\ \ CO2\ in\ ppm$$

Then the forcing is calculated using the equations:

$$CO2\ not\ captured\ by\ the\ Sim\ \ =\ 2.46\ ppm\ \ -\ Sim's\ default\ CO2\ values\ in\ ppm$$

$$New\ CO2\ ppm\ \ =\ \ (CO2\ in\ ppm\ +\ CO2\ not\ captured\ by\ the\ Sim\ \ )\ *\ year$$

$$Simulated\ GlobalCO2\ \ =\ \ (New\ CO2\ ppm\ \ +\ \ 419\ ppm)$$

$$log(SimulatedGlobalCO2ppm/280)/log(2)\ \ = forcing$$

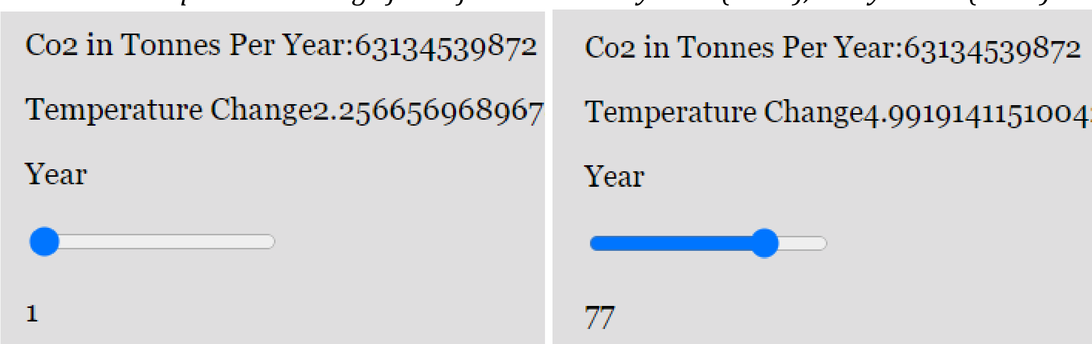
As a reasonable estimate for the expected growth in CO2 emissions per year is 2.46 ppm (MacKay, 2023), the current atmospheric CO2 ppm is 419 (NASA, 2023), and the pre-industrial CO2 ppm is estimated to be 280 ppm (Lindsey, May 2023)

Finally the temperature change is calculated using the equation:

$$3\ *\ forcing$$

Reasonable estimates puts the climate sensitivity around 3 F (IPCC, 2007)

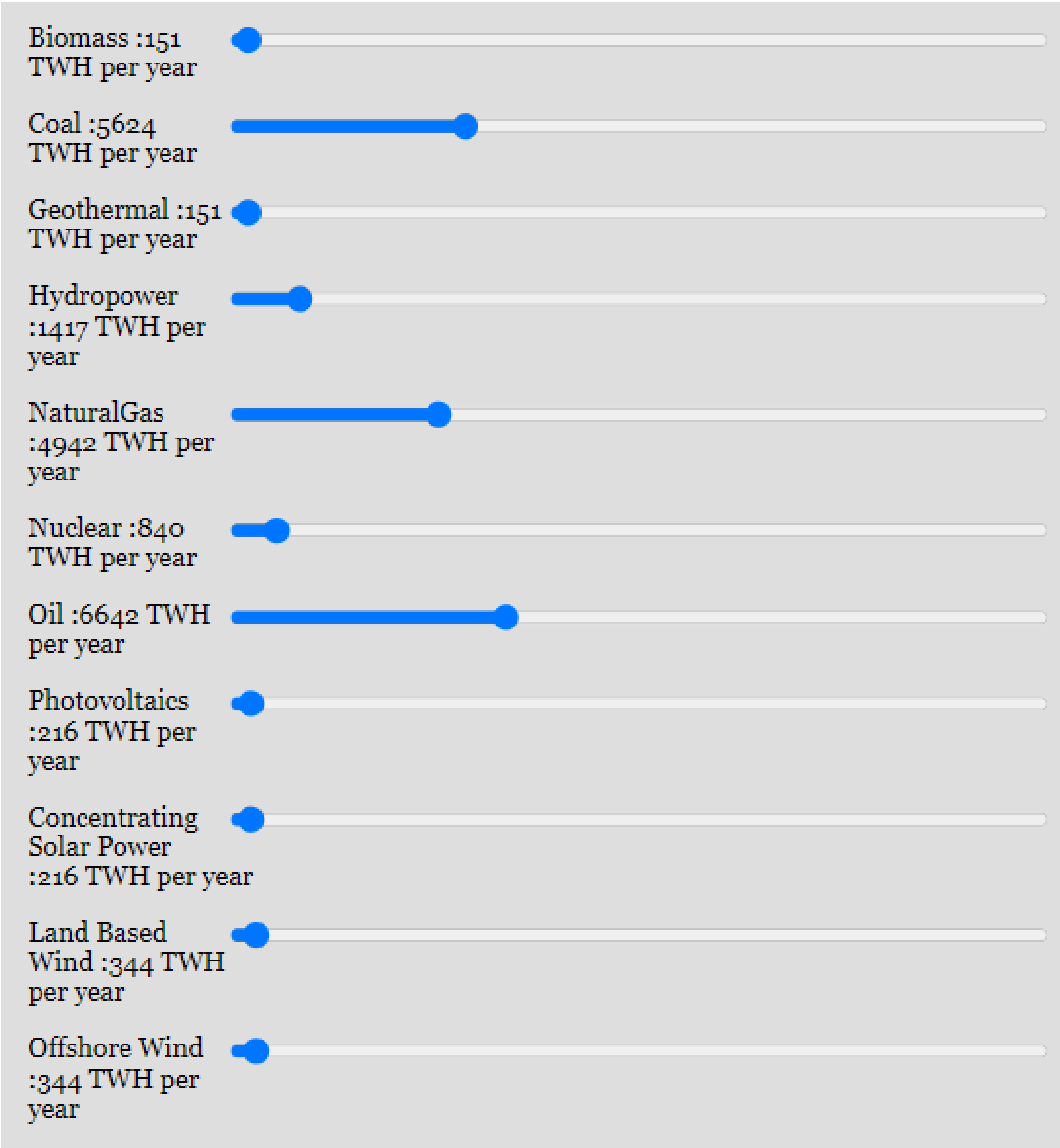
Figure 3 Screenshot of the results page for the ECA climate model. The screenshots display the model's temperature change for default values at year 0 (2023), and year 70 (2100).



Results

In total the model has a total of 6 topics, and 44 anthropogenic sources of carbon. Each source's emission value can be modified by the user to generate new climate scenarios.

Figure 4 Screenshot of the energy topic page for the ECA climate model. The screenshot shows each energy source the model tracks set to their default values.



The CO2 rise from sources captured by the model is 3.59 ppm a year. This is more than the projected global CO2 rise of 2.46 ppm per year *(MacKay, 2023)*. Overall most categories overshot their expected CO2 rise.

Table 1: *Compares the values of yearly CO2 emissions calculated by the ECA climate model with expected values from Rachel White Greenhouse Gasses (White, 2023) and percentage of global emissions. Percentage of global emissions was calculated using 2.46ppm as the total global emission per year (MacKay, 2023).*

Topic Category	Yearly CO2 emissions as calculated by ECA	Percent of total global CO2 emissions	Expected percent of total global CO2 emissions
Travel	0.45 ppm	21%	17.3%
Food	0.75 ppm	35%	0%
Energy	0.78 ppm	37%	38.8%
Industry	1.27 ppm	59%	20.9%
Land Use	0.22 ppm	10%	12.1%
Residential and Commercial	0.01 ppm	4.6%	7.5%

The model predicts a rise of 2.24 F in global temperature today from pre industrial levels. The best estimate of the actual rise is between 1.9 F - 2.75 F (NASA, 2022; Lindsey, January 2023). Which the model's prediction falls within. The model predicts that by 2100, if no changes are made the global temperature will increase by 4.9 F. Reasonable estimates place global temperature rise by 2100 at between 3 and 12 degrees F (United States, 2014). Overall the model overshot expected CO2 emissions but fell within a reasonable range for temperature prediction.

Discussion

For each category the model overshot the expected CO2 emissions per sector. This is despite the fact the carbon sources from each section are not comprehensive enough to be the source of all carbon dioxide emissions for that sector. This is likely due to two causes, research and model limitations.

While there was extensive research done the model was hampered by not having the information needed readily available. When the model was conceived the hope was that there would be accessible information about anthropogenic carbon due to specific sources. For example, how much carbon dioxide is emitted by people commuting to work by car globally. Unfortunately, this kind of information was often reported on a national scale, outdated, from questionable sources, or missing entirely. This impeded development of the model and made its results far less reliable. Further expansion of the project would benefit from partnering with a research scientist to develop a more substantive justification for the ECA model's inputs.

Additionally, for many of the carbon sources researched their numbers were reported in total CO_2 emissions related to the activity. This causes CO_2 emissions to be duplicated in the model, as for example any energy or car use accounted for in the total emission of the source would be double counted in the Travel or Energy sectors. This gets at the model limitation mentioned above. Currently the model isn't able to track multiple effects, only CO_2 emissions. For example, many of the industry CO_2 sources are energy intensive. In reality if we switched over to 100% clean energy the industry sector would also see a drop in CO_2 emissions despite not having made any changes. At the moment the model can't track these kinds of changes. It is completely within the scope of the technical capabilities of the model but it had to be shelved due to insufficient available research with that level of detail.

The model's temperature predictions are within a reasonable range of estimates. However it is on the low side for both its predictions of rise from preindustrial to now, and from preindustrial to 2100. This is due to model limitations. The model does not incorporate several key variables like expected population rise, increased energy efficiency, nor the increased emissions required to support a fifth of the world escaping poverty (Gibbs, 2017). The model is fully capable of including these variables but additional design and research work would be required. Furthermore it would be ideal to create a user-friendly way to see and modify these assumptions from within the application, instead of requiring a collaborator to edit the data within the application manually.

There are a number of potential expansions for the project. As discussed above, further and more comprehensive research to justify model assumptions, adding more complexity to ECA's modeling, and providing a user-friendly way to see and modify ECA's assumptions would greatly improve the reliability of the model. Looking forward, there are a number of more tertiary improvements to be made as well. For example, additional languages would expand its use as an educational tool. Overall, further refinement of the model over time will allow it to continue to improve.

The ECA model is designed to be used for public education. Its purpose is to help the average citizen conceptualize how human actions affect CO2 emissions and thus the global temperature. Over the next few years the world at large will need to make choices on what actions they are willing to take on climate change and what they are willing to live with as a consequence. There are a number of bad actors looking to muddy the waters and encourage interia for their own personal gain, working to convince the world that those choices aren't for them to make (Treen, 2020). However, in democracies we make those choices at the ballot box. ECA's goal is to help make those choices visible and to encourage citizens to exercise their rights to decide the world they want to live in.

Conclusion

The ECA-Effective Community Action model is designed to predict global temperature changes over time given changes to modeled anthropogenic carbon sources. The model overshoots estimated global carbon emissions by 1.13 ppm a year, but its temperature predictions are within a reasonable estimate (MacKay, 2023; NASA, 2022; Lindsey, January 2023).

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