Evaluating Equity in Renewable Energy

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Abstract

With the emerging energy crisis caused by non-renewable fossil-based energy sources and the burning of fossil fuels causing significant amounts of greenhouse gas emissions, leading to anthropogenic climate change and global warming, the need for renewable energy sources that can contribute to a carbon neutral society has become a priority in the energy sector. The rapid development of renewable energy sources and the robust integration of renewable energy sources into the grid indicate that the United States is successfully transitioning into clean energy and achieving net zero emissions. The inclusion of impoverished and historically underrepresented groups and communities will be a critical aspect in determining when the United States will reach net zero emissions. This review focuses mainly on the evaluation of equity in the current energy infrastructure by defining and evaluating energy equity metrics and determining methods that can be implemented in two predominant renewable energy sectors, wind and solar to improve equity. There is data that indicates that renewable energy inequity does exist, along with data to imply that actions are being taken to fix inequities. However, the rate at which practices are done to improve equity in this sector need significant improvement.

1. Introduction

According to the Sustainable Development Goals, a set of 17 goals focused on creating a better and sustainable future for everyone, one of the most fundamental goals is SDG # 7: Affordable and Clean Energy.[1] While the United States is considered to be in good standard of achieving the standards and criteria set by that metric, a perfect indicator to determine the current state that the United States is in achieving the goal is the evaluation of equity in the energy sector, with an emphasis on the renewable energy sector. By measuring equity in the renewable energy sector, there is a focus on the inclusion of historically underrepresented, marginalized, and impoverished groups and/or populations in the United States that are often the latest to receive economic, social, and environmental benefits of technologies and are often the most negatively impacted by changes.[4] By measuring the current state of equity in renewable energy, there can be a more finite statement on where the United States stands in terms of accomplishing SDG # 7 and more importantly of reaching carbon neutrality and net zero emissions by the year 2050.[2] By determining what equity means in energy, defining metrics to measure equity in energy, and then evaluating equity in energy, there will be a good indicator to determine how much the United States needs to do to improve the implementation and integration of renewable energy systems as it transitions away from fossil fuel energy resources.[3] In addition, the most equitable societies tend to be the most prosperous societies from a global perspective.

2. Defining Equity

Equity is defined as just and fair inclusion, where all members of society can participate and prosper due to conditions allowing individuals of different backgrounds and identities to reach their full potential.[10] Equity has quite a broad definition and there are several subcategories within equity. By utilizing the subcategories of equity, key metrics can be determined in the context of energy to determine the current level of equity in American society. [10]

2.1 Subtypes of Equity

In the scope of this paper, five types of equity will be defined and discussed. The five types of equity are procedural equity, distributional equity, structural equity, transgenerational equity, and transformational equity.[10]

2.1.1 Procedural Equity

Procedural equity is the inclusive, accessible, and authentic engagement and representation in the process to develop or implement different types of programs and policies focused on equity.[10] In the scope of this paper, procedural equity will be simplified as the representation in the form of diversity and inclusion in the creation of programs and policies.

2.1.2 Distributional Equity

Distributional equity are the programs and policies that result in a just and fair distribution of benefits and burdens across all segments of a community, while prioritizing groups, communities, and individuals that have the highest need.[10] In the scope of this paper, distributional equity will be simplified as the programs and policies that create fair distribution.

2.1.3 Structural Equity

Structural equity is defined as the decisions that are made to institutionalize accountability. This includes the decisions that are made with the consideration and recognition of historical, cultural, institutional, and systemic dynamics, structures, and systems that have routinely advantaged privileged groups in society and create disadvantages and unequal access and opportunity for groups that are minorities and/or disproportionately represented.[10] In the scope of this paper, structural equity will be simplified as the systems and policies that can be held accountable to ensure equity for historically underrepresented minorities.

2.1.4 Transgenerational Equity

Transgenerational equity are the decisions that consider the generational impacts stemming from inequities and injustices of previous decisions and aim to minimize or eliminate unfair burdens on future generations.[10] In the scope of this paper, transgenerational equity will be exclusively used to determine methods of improving equity and will be simplified as decisions to create change that will lead to equity.

2.1.5 Transformational Equity

Transformational equity is the ideology that communities and cities have the independence and indigenenous capacity to internally govern and sustain themselves.[10] Simultaneously, communities can externally voice, influence, and take part in regional, state, and/or national policy making and decision-making affairs. Similar to transgeneration equity, transformational equity will exclusively be used to determine methods of improving equity and will be simplified as policies that create independence and self-sufficiency in communities, with an emphasis on impoverished communities and historically marginalized and underrepresented communities.

3. Metrics to Track Subcategories of Equity

To evaluate the equity in energy, metrics will be defined to measure and indicate the degree of equity in the five subcategories of equity. The metrics used will help evaluate the scope of the different subcategories. Most, but not all metrics will come from the Clean Energy for Low-Income Communities Accelerator (CELICA)[6] and take into account the objectives stated in the seventh United Nations Sustainable Development Goal: Affordable and Clean Energy.[1] These metrics will utilize a systems thinking approach that focuses on the three pillars of sustainability: social, economic, and environmental development based on the guidelines included in the Life Cycle Sustainability Assessment.[8]

3.1 Metrics for Procedural Equity

The metrics used to evaluate procedural equity will be focused on major federal policies and/or programs created over the last decade that focus on improving or implementing clean, renewable energy.[6] Within each of these policies and/or programs, there will be an extensive analysis of the people behind the policies such as lobbyists, politicians, policy writers, and other groups of interest and determine the proportion of people involved identified as underrepresented minorities with respect to the proportion of underrepresented minorities and ethnicities as listed in the United States census. If the proportion of people involved in clean energy that identify as underrepresented minorities are greater than or equal to the proportion of underrepresented minorities and ethnicities listed in the United States census, that would indicate that procedural equity is adequate and has been achieved. Simultaneously, if the proportion of people involved that identify as underrepresented minorities are less than the proportion of underrepresented minorities and ethnicities listed in the United States census, that would indicate that procedural equity has not been reached and needs to be improved.

3.2 Metrics for Distributional Equity

Similar to procedural equity, distributional equity will focus on major policies and/or programs that focus on improving and/or implementing clean, renewable energy within the span of the last ten years.[6] The metrics for distributional equity will take into account the participation or the measure of allocation within these policies, low income parity, and energy burden.

3.2.1 Participation

Participation looks at the correlation coefficient between the household served with clean energy and the income level of that household.[6] If there is a strong correlation or a high r-squared value, where one can assume income and number of households are directly proportional, the participation component for distributional equity can be assumed to be poor and need significant improvement. If there is a weak correlation or a high r-squared value, where one can assume income and number of households are unproportional, the participation component for distributional equity can be assumed to be achieved with a high level of confidence. If there is no correlation, where one cannot assume income and number of households have a relationship, the participation component for distributional equity can be assumed to be adequate, with high uncertainty and a low level of confidence.

One possible error that may arise from this test is the event of causation instead of correlation. Another possible source of energy is that natural gas is considered to be a clean energy source, while it emits methane, a greenhouse gas that is more potent that carbon dioxide.

3.2.2 Low Income Parity

Low income parity looks at the market penetration by income and provides savings and incentives to people who are in neighborhoods and communities that are identified as low-income, impoverished, or historically neglected.[6] This will look at the renewable energy incentives in the form of grants and tax incentives with respect to income level. If there is a negative or a weak correlation between income and the amount of grants and tax incentives available where one can assume a strong inverse relationship, it can be stated with a high degree of confidence that low income parity has been achieved, which contributed to distributional equity. A strong correlation between income and the amount of grants and tax incentives available where one can assume a direct relationship, it can be stated that low income parity needs significant improvement. If there is not a strong or weak correlation, it will be indecisive to determine whether or not low income parity has been achieved.

Possible sources of error may include that different regions of the United States may have different costs of living, which may affect low-income status and thus access to grants and tax incentives.

3.2.3 Energy Burden

Energy burden is defined as the percentage of gross household income spent on energy costs. To compute the energy burden for each family, the percentage reduction in the percentage of income paid for energy bills for different income levels is calculated.[6] If the energy burden reduction rate is constant or significantly higher for low-income and middle-class households are approximately the same or significantly higher than higher income households, it can be stated that energy burden is contributing to distributional equity.

3.3 Metrics for Structural Equity

Structural equity will be the most fundamental measure of equity in the scope of this paper, as metrics for structural equity will determine equity on the local level on the basis of the three pillars of sustainability: economic structural equity, social structural equity, and environmental structural equity.[8]

3.3.1 Economic Structural Equity: Workforce Development

The main metric to measure the level of economic structural equity that is tracked is workforce development. The transition to cleaner, sustainable, and renewable energy sources are linked to the creation of approximately four million new jobs in the renewable energy sector, the energy storage and advanced grid sector, the energy efficiency structure, and the advanced vehicles structure. The transition from fossil based energy sources to cleaner energy sources also involves the defunding of fossil based industries such as coal, causing losses in fossil fuel jobs, with over one hundred thousand jobs being lost in the fuel industry in July 2020, a number that may exponentially increase.[3]

The first component in determining the level of economic structural equity in workforce development is the proportion of jobs lost in the fossil fuel industry that belonged to minorities, compared to the proportion of minorities in the United States. If the proportion of jobs lost in the fossil fuel industry that belonged to minority groups compared to the proportion of minorities in the United States 2020 census is approximately the same, there will be economic structural equity in the fossil fuel sector under workforce development.

The second major component in determining the level of economic structural equity in workforce development is the economic opportunities in the renewable energy sector for underrepresented minority groups. This applies to new jobs in the renewable energy sector and business, management-oriented, entrepreneurial opportunities and resources in the renewable energy sector. If the proportion of jobs gained in the renewable energy industry that belonged to minority groups compared to the proportion of minorities in the United States 2020 census is approximately the same, there will be economic structural equity in the renewable energy sector under workforce development. The same applies for business, entrepreneurship, and management-oriented opportunities.

3.3.2 Social Structural Equity

Unlike economic structural equity and the other metrics, social structural equity focuses on the societal level of these policies. The major questions that are examined are "Who are the people in charge of regulating, maintaining, and protecting policies?" and "What actionable items are done to ensure that these policies make a societal impact?" Most of the data and conclusions will not be quantitative, but instead qualitative. Social structural equity helps determine if the proposed policies and programs are successfully creating the proposed changes within their scope and ensure that these policies and programs are changing society and improving society to be more equitable. A thorough analysis of the social structural equity for different policies and programs can provide meaningful and insightful insight towards improving policies and programs in a manner where they can make a much larger societal impact.

3.3.3 Environmental Structural Equity

In the scope of this paper, environmental structural equity will predominantly be measured by health and safety metrics. While there are other metrics to take into consideration such as the location of pollutants and power plants in proximity to neighborhoods that are historically neglected and consist mainly of underrepresented minorities, health and safety with respect to energy usage will be the primary indicator. Specifically, environmental structural equity will measure the percentage of homes and the respective frequency of health and safety issues cited that deal with energy usage and the number of homes and their respective frequency of health and safety energy-related issues.

3.4 Metrics for Transgenerational Equity

No metrics will be used to evaluate transgenerational equity in this study due to the lack of available data that provides meaningful and insightful conclusions.

3.5 Metrics for Transformational Equity

No metrics will be used to evaluate transformational equity in this study due to the lack of available data that provides meaningful and insightful conclusions.

4. Evaluating Metrics

4.1 Evaluating Procedural Equity

The process of evaluating procedural equity was executed by collecting data, interpreting and evaluating the data into a visualization, and finally interpreting the meaning of the data with respect to the conditions mentioned for just and fair procedural equity.

4.1.1 Collecting Data for Procedural Equity

According to the metrics used for evaluating procedural equity as stated in Section 3.1, the main data types needed to determine procedural equity include (1) the federal policies and/or programs that relate to clean, renewable energy infrastructure and implementation over the last ten years, (2) the federal policies and/or programs that relate to clean, renewable energy infrastructure and implementation that specifically focus on the inclusion of historically underrepresented minority groups and impoverished communities through the lens of environmental and energy justice,[14] and (3) the demographic of the people and legislators behind the policies.

The collection of data for the first data point came from the National Conference of State Legislatures (NCSL) online database.[14] The NCSL database provides metrics on the bill name, the year a bill was proposed, the main subcategory and/or topic of interest for the bill (i.e Energy Policy and Clean Energy), the current status of the bill (i.e. failed, enacted, vetoed, pending, etc), the date of the last action on the bill, the congressional authors and legislators behind the bill, subtopics and keyword identifiers within the scope of the bill (i.e Renewable Energy), and a short summary of the purpose of the bill, which includes the issue the bill hopes to address. By filtering the database for only energy entries that relate to renewable energy as a subtopic, there was a collection of several entries of bills stemming from the time of this paper 2008 to the date of this paper. Data from the database was copied and cleaned into Table 1: Procedural Equity. Due to the considerable amount of data, only the 2021 data was presented into Table 1.

By utilizing the data from the previous section, the data was further cleaned to determine renewable energy bills that exclusively focus on addressing and fixing energy and environmental injustice issues in underrepresented and impoverished communities and demographic groups. To clean the data, a search filter tool was used with keywords: equity, justice, inequality, injustice, environmental justice, fair, etc being used to determine the bills that can be classified into this subcategory. Due to time constraints and the large amount of data utilized, extracting the data in this manner was very efficient. While this methodology may have left a source of error in future steps of data analysis, there is a very high certainty that this methodology was fairly accurate and can present key points in the data extraction methods.

The final data point, which focused on the demographic of the people and legislators behind bills and policies was unfortunately neglected in the scope of this paper. Even though the list of legislator names provided the opportunity to determine the demographic of legislators, the methodology of collecting data to determine the demographic of the legislators was determined to be inefficient, and a significant source of error due to the lack of insightful and meaningful information that can be extracted from the data to form conclusions. Furthermore, the absence of other key stakeholders and participants in the development of bill creation is a very significant source of error. Due to the points mentioned, the demographics of the legislators and bill proposals were not used in this study.

4.1.2 Interpretation & Evaluation of Data into Visualizations for Procedural Equity

To accomplish the objective of determining the level of procedural equity in the United States, the collection of data in Section 4.1.1 was interpreted and evaluated to create insightful visualizations. Upon looking at the data metrics under section (2) with respect to the data under section (1) of the data analysis, the results did not yield insightful or impactful data. Rather, the data was very concerning. From the years 2008 to 2014, there was no bill in the database that focused on renewable energy in the scope of energy justice, energy equity, or environmental justice. While that changed in 2014, there was consistently only one bill presented that addressed the issue up until 2018. While there may be political, social, and economic reasons to explain the reasons for the lack of data in these sectors, the lack of meaningful data that could be utilized in visualizations lead to the omission of those data points. Simultaneously, the lack of renewable energy focused bills and overall number of bills as compared to the number of bills in a normal calendar year in 2020 due to the COVID-19 pandemic lead to the omission of 2020 into data and evaluation. This resulted in the use of two sources of data for section (1) and section (2) of data, the years 2019 and 2021.

The lack of data for visualizations prevented the use of some common data visualization structures such as line graphs and column charts. In addition, the relatively small proportion of renewable energy bills focused on creating equity compared to the number of bills that were focused on all areas of renewable energy made visualizing that proportion very difficult. Due to these difficulties, an emphasis was placed on the bills focused on renewable energy justice and equity. The data yielded two different pie charts**,** Figure 1 and Figure 2, that provided insight on the current status of equity in procedural justice.

4.1.3 Interpreting Visualizations for Procedural Equity

While there is a growing amount of attention allocated in the form of bills and discussing to fix and address procedural equity in the renewable energy sector for impoverished communities, the very low proportion of bills in renewable energy that focus on equity and justice in compared to the number of bills on renewable energy, there is a high need for exponential growth in bills proposed. Procedural equity will play a fundamental role in creating equity in renewable energy and an emphasis on renewable energy justice in future bills will help promote and accelerate equity.

4.2 Evaluating Distributional Equity: Participation

The process of evaluating distributional equity, more specifically into the participation subcomponent is executed similarly to the process of evaluating procedural equity. The collection of data was completed first. Next the interpretation and evaluation of data was conducted into a visualization. Last, the evaluations on the current state of participation in the category of distributional equity yielded interpretations of data visualization and conclusions were made to interpret the degree of equity in participation in renewable energy.

4.2.1 Collecting Data for Distributional Equity: Participation

According to the metrics stated in Section 3.2.1, the main data types needed to determine and evaluate procedural equity include (1) households served with clean energy, where clean energy is defined as energy from renewable energy resources such as electricity from wind and solar panels and (2) the income median level for a household or a family in the area that can be identified as a beneficiary of clean energy. The negative environmental impacts that come with the use of natural gas such as methane and the danger associated with nuclear power will not be used in section (1) of this data analysis. Simultaneously, other renewable energy sources that are not widely implemented such as geothermal systems and biomass electricity generators will not be used due to the lack of infrastructure and rapid commercialization. While these energy systems are renewable, there is very little data that can be used to make rational conclusions and will also not be used in section (1) of this analysis.

The collection of the first data point that quantifies clean energy for households came from the Environmental Protection Agency (EPA). Specifically, the data comes from Green Power Communities (GPCs),[12] which are towns, villages, cities, or counties in which the local government, businesses, and residents collectively use green power in amounts that meet or exceed EPA's Green Power Community usage requirements. According to the EPA, green power is defined as a subset of renewable energy and represents those renewable energy resources and technologies that provide the highest environmental benefit**.**[19] Since wind power and solar energy are the most abundant forms of renewable energy in the United States, it is assumed that the majority of green power from GPCs come from solar panels and/or wind turbines. Other renewable energy sources that help a community become a GPC are assumed to be very small or negligible. The EPA GPCs online dataset provides a list of communities in the United States that identify as GPC cities along with key metrics. The first key metric is the annual green power usage in kilowatt hours. The second is the proportion of green power usage with respect to total electricity usage in percentages. While these metrics are not inclusive of the majority of the United States population, the quantity of data points can be used to determine the current state of distributional equity in the form of participation in renewable energy systems in the United States. Data from the online database was directly copied, pasted and reformatted into a data table for analysis with section (2) of participational distributional equity.

With the collection of data about clean energy consumption and usage in the United States GPCs, the average median income was determined for each household. Due to the lack of datasets and raw databases that provide median income based on a community level available for easy access and download, the methodology of data extraction and insertion was different for this section compared to section (1). The collection of this data came from Data USA[8] and was extracted by utilizing data mining techniques within Google Sheets App Scripts functionality. Two functions, addIncomeValue(), and getIncome() were used to extract data to the Google Sheet.

```
function getIncome(city) {
  let url = "https://datausa.io/profile/geo/" + city.trim() + "/";
  let data = UrlFetchApp.fetch(url);
  let index = data.getContentText().indexOf("Median Household Income");
  let incomeSummary = data.getContentText().substring(index,index+75);
  let medianIncomeNum = incomeSummary.substring(incomeSummary.indexOf("$"));
  return medianIncomeNum.substring(1, medianIncomeNum.indexOf("<"));
}
```

The function, getIncome() takes the name of a city as a parameter from addIncomeValue(), extracts data from a query search of Data USA website, cleans the data from raw, hard to read hypertext markup language script into a readable form, and finally returns the median income level of that city in United States dollars (USD) in 2019, which is used in function addIncomeValue().

```
function addIncomeValue(){
  let values = SpreadsheetApp.getActiveSheet().getDataRange().getValues();
  for(let i = 1; i < values.length; i++){
      values[i][3] =
      getIncome(values[i][0].substring(0,values[i][0].indexOf("Community")).to
      LowerCase().replace(", ", "-"));
  }
}
```

The function, addIncomeValue() iterates through the name of each GPC in column 1, calls getIncome() for the corresponding GPC and sets the median income household value in the cell to the immediate right of the GPC in Table 2.

While the majority of the values of the addIncomeValue() successfully added the median income level of the respective GPC community, it should be noted that extracting data through this methodology was not very efficient as approximately 37% (41/110) of the available data points did not return an income. The GPC communities that did not return an income were hidden and not used for the interpretation and evaluation components for evaluating distributional equity in the form of participation.

4.2.2 Interpretation & Evaluation of Data into Visualizations for Participation

As mentioned in Section 3.2.1, the relationship between the two data points, clean energy usage and the corresponding median income level are a good indicator to determine equity in distribution equity in the form of participation. The best way to determine the relationship between two variables is through a line graph and determining the r-squared, goodness of fit value between the data points.

Therefore, by plotting graphs of annual green power usage and the corresponding median household income value in 2019 along with a graph of the percentage of green power usage with respect to the total electricity usage versus the median household income value, a relationship between the two variables can be decided. By using the Google Sheets scatter plot chart functionality, the value of r-squared goodness of fit was initially calculated. However, by further analyzing the graphs and observing the presence of extreme values, it was determined that the data was being skewed by these values. For the purposes of analyzing the relationship between these two variables, outliers were removed to improve the linearity between the two variables. The results of the two linear regression functions can be found in Figure 3 and Figure 4. Figure 3 shows the graph of the Annual Green Power Usage (kWh) vs. Average Income (Household, 2019) (USD) while Figure 4 shows the graph of the Green Power % of Total Electricity Use vs. Average Income (Household, 2019) (USD).

4.2.3 Interpreting Visualizations for Participation

As shown in the corresponding participation diagrams in Figure 3 and Figure 4, there is a very weak correlation between average income and average green power usage. The scatter plot appears to be very random and might suggest that there is equity in which GWCs are being formed and created. As for the green power percentage use, there is a stronger correlation to imply that the percentage of green power usage with respect to average household income. While there is a very low r-squared goodness of fit value, there appears to be an exponential trend with one withstanding outlier in the average household income. Overall, the data does not imply inequity in participation, but due to the lack of data points for usage and outliers in the data points, it is currently uncertain to make a finite conclusion.

4.3 Evaluating Distributional Equity: Low Income Parity

Evaluating the low income parity subcategory of distributional equity provides insight to economic policies and incentives to level inequities in renewable energy ownership and/or due to low income status. The process of evaluating low income parity is similar to the methodologies used in evaluating participation in distributional equity and procedural equity. Data is collected, and there is an attempt at interpreting and evaluating the given data. However, unlike those two methods, low income parity lacks a significant conclusion.

4.3.1 Collecting Data for Distributional Equity: Low Income Parity

According to the metrics stated in Section 3.2.2, the key data points to measure and determine the degree of low income parity, with respect to distributional equity, will involve the income of households and neighborhoods. Simultaneously, a quantitative number for grants, savings and incentives is the second data point that will be measured. The two data points will be simplified into two sectors: (1) the median income of a household based on a zip code and (2) the total amount of grants, tax benefits, and other related economic incentives available based on a zip code. These two data points will provide insight to the accessibility and feasibility between zip codes and American neighborhoods of different income levels and tax brackets.

The collection of data from the first major data sector has a similar methodology to the methodology used to extract data in Section 4.2.1. The first component of getting the median income of a household based on a zip code is to get a list of zip codes. However, there is no available dataset that is easily accessible online that contains all of the zip codes in the United States. However, there is a dataset that contains a general overview of the zip codes by each state.[15] By cleaning that data, a sizable amount of zip codes could be used for further analysis. Due to the substantial differences in sizes of cities and different levels of income inequality in different areas of a city, a zip code will be used as an alternative metric to a city.

By using zip code instead of cities, it is less likely for the data to be skewed for median income due to income inequality in different areas.

```
function addZipCodes() {
  let values = SpreadsheetApp.getActiveSpreadsheet().getSheetByName("Low
Income Parity").getDataRange().getValues();
  let count = 1;
  for(let i = 1; i < values.length; i++){
    let index = values[i][1].indexOf("thru");
    if(index != -1){
      let start = Number(values[i][1].substring(0,index));
      let end = Number(values[i][1].substring(index).substring(5))
      for(let index = start; index <= end; index++){
        SpreadsheetApp.getActiveSpreadsheet().getSheetByName("Low Income
Parity").getRange("C" + count).setValue(values[i][0]);
        SpreadsheetApp.getActiveSpreadsheet().getSheetByName("Low Income
Parity").getRange("D" + count).setValue(index);
        count++;
      }
    }
    else{
      SpreadsheetApp.getActiveSpreadsheet().getSheetByName("Low Income
Parity").getRange("C" + count).setValue(values[i][0]);
      SpreadsheetApp.getActiveSpreadsheet().getSheetByName("Low Income
Parity").getRange("D" + count).setValue(values[i][1]);
      count++;
    }
  }
}
```

The function, addZipCodes() iterated through a list of zip codes that were listed as State Name (Starting Zip Code thru Ending Zip Code). By extracting the state, followed by the first and last numbers from that dataset, the different zip codes corresponding to each state were produced in column one and column two of Table 3**.** It should be noted that while the dataset provided a large number of zip codes, there were several zip codes that were missing. For example, the zip code for Ithaca, NY, 14850, and the zip code for Cornell University, 14853 were not extracted from this dataset.

The next major component of the first major data sector involves getting an income that corresponds to getting the median income for a given zip code. Similar to the methodology for getting the median income for a city in section 4.2.1, data mining is executed due its high efficiency and the lack of datasets for getting income for a zip code area. The functions updateCell() and getIncome() work similarly to getIncome() and addIncomeValue() in section 4.2.1. This time, the data is extracted from Income By Zip Code.[20]

```
function updateCell(){
  let values = SpreadsheetApp.getActiveSpreadsheet().getSheetByName("Low
  Income Parity").getDataRange().getValues();
  for(let i = 1; i < values.length; i++){
    let state =
      values[i][2].substring(0,values[i][2].indexOf("(")).toLowerCase().trim()
    let zip = Math.round(values[i][3]);
    SpreadsheetApp.getActiveSpreadsheet().getSheetByName("Low Income
Parity").getRange("E" + i).setValue(updateIncome(state,zip));
  }
}
```

Similar to addIncomeValue(), updateCell() iterates through the zip codes generated by addZipCodes(), and then calls getIncome() for the corresponding zip code and state to get and set the median income household value in the cell to the immediate right of the zip code of interest. It should be noted that Income By Zip Code returned a median income at a much higher rate compared to Data USA.

```
function getIncome(state,zipCode){
  let data = UrlFetchApp.fetch("https://www.incomebyzipcode.com/" + state +
"/" + zipCode + "/");
  let keyDataString1 =
data.getContentText().substring(data.getContentText().indexOf("The median
household income"));
  let keyDataString2 =
keyDataString1.substring(29,keyDataString1.indexOf(")"));
  if(data.getContentText().indexOf("<h2>Median Household Income</h2>") == -1){
    return "";
  }
  else{
    return keyDataString2;
  }
}
```

The function, getIncome() works very similarly to the getIncome() function in Section 4,2.1. It takes the state name and the zip code as a parameter from updateCell(), extracts data from a query search of Data USA website, cleans the data from raw, hard to read hypertext markup language script into a readable form, and finally returns the median income level of that city in United States dollars (USD) in 2019, which is used in function addIncomeValue().

The second sector used, the total amount of grants, tax benefits, and other related economic incentives available based on a zip code provided challenges. There are websites that provide information for the costs of implementing a renewable energy technology, mainly a solar farm, in your area. However, these sources often do not provide a descriptive breakdown of how the cost was calculated or if the cost is with or without tax credits, grants, and other financial incentives to renewable energy. The best source for providing this information was determined to be the Database of State Incentives for Renewables & Efficiency (DSIRE).[9] The DSIRE website content dynamic generation process as compared to the static generation process of the previous two websites made the process of data extraction from the site impossible. However, DSIRE publishes database archives on their website. By utilizing the dataset, Table 4 was created in an attempt to determine the corresponding zip code with a policy or a grant. However, upon attempting to merge the two zip codes, there were no zip codes with the average median listed that corresponded to a grant or incentive in their database.

Due to the lack of data points that correspond to the two sectors, no relationship was found between the average median income and the amount of grants available and no conclusion can be drawn about the current state of distributional equity through the lens of low income parity on a federal level. However, on a local and state level, there may be data available to draw conclusions from data.

4.4 Evaluating Distributional Equity: Energy Burden

The evaluation of distributional equity in the energy burden subcategory is very different from other subcategories of equity since energy burden is an area that has been researched and discussed previously in the context of energy justice, energy efficiency in the American household, and is often a topic for discussion when measuring the current state of energy in the United States. Due to the abundant research on energy burden conducted by the United States Department of Energy Office of Energy Efficiency and Renewable Energy, there is no need to collect data, interpret data, or even interpret visualizations as they release energy burden results.[15] From the report, it appears that the energy burden among low income communities in the United States is still an issue that needs to be addressed, but the energy burden is becoming lower and is improving over time as technology improves and systems become more energy efficient. The Department of Energy's Weatherization Assistance Program and State and Local Solution Center also provides solutions for issues that have arisen with energy buden.[15] Compared to the other metrics and subcategories for determining distributional equity, energy burden is the closest towards creating an equitable solution.

4.5 Evaluating Structural Equity: Economic Structural Equity

Evaluating the economic subcategory of structural equity provides insight on the current structure of renewable energy with a focus on the economic pillar of sustainability. The process of evaluating economic structural equity focuses on workforce development. More specifically, measuring economic structural equity determines the equity and opportunity in the energy sector of the United States workforce.

4.5.1 Collecting Data for Economic Structural Equity

According to the metrics stated in Section 3.3.1, the key data points to measure and determine the degree of economic structural equity will involve looking at the diversity and inclusion makeup of the energy sector workforce. The main data points analyzed will be simplified into three sectors that focus on proportions: (1) the demographic proportions of workers in the fossil fuel industry, (2) the demographic proportions of workers in the renewable energy sector, and (3) the demographic proportions in the United States Census. These three data points will provide insight to the degree of equity and provide insight on points of equity that need to be improved upon amongst these industries.

The collection of data for the first data sector came from the 2019 United States Energy and Employment Report (USEER).[2] The USEER provides data on the workers in the major energy sectors. For data on the fossil fuel industry, the electric power sectors of coal, natural gas and oil were examined. By determining the number of people for the five demographic races/ethnicities, Hispanic or Latino, American Indian or Alaska Native, Asian, Black or African-American, Native Hawaiian or Pacific Islander, and White, listed in the United States Census[5] from the report and the total number of workers in the fossil fuel industry, the proportions of each of the five demographic groups were
determined by dividing the number of workers from a demographic in the fossil fuel industry over the number of workers in the fossil fuel industry.

Similar to the collection of data for the first data sector, data for the renewable energy sector came from the USEER. For data on the renewable energy sector, the electric power sectors of wind power, solar energy, hydroelectric, and biomass were examined. By determining the amount of workers for the five demographic races/ethnicities as listed in the United States Census from the report and the total number of workers in the renewable energy industry, the proportions of each of the five demographic groups were determined by dividing the number of workers from a demographic in the renewable energy industry by the number of workers in the renewable energy industry.

The final data sector involved no cleaning or further examination. The United States Census (**Cite)** data from the most recent, 2020 census was collected by looking at the percentage of Hispanic or Latino, American Indian or Alaska Native, Asian, Black or African-American, Native Hawaiian or Pacific Islander, and White that are in the United States.

4.5.2 Interpretation & Evaluation of Data into Visualizations for Economic Structural Equity

To accomplish the objective of determining the level of economic structural equity in the United States, the collection of data in Section 4.5.1 was interpreted and evaluated to create insightful visualizations. The data sectors of (1) the demographic proportions of workers in the fossil fuel industry, (2) the demographic proportions of workers in the renewable energy sector, and (3) the demographic proportions in the United States Census needed to be visualized in a method that could easily determine any differences in demographic and determine a form of economic structural inequity in either sector of the energy workforce.

One of the best data visualization tools that is used is a column/bar chart. The chart provides a qualitative view of the differences and also can be labeled to indicate quantitative differences amongst the different demographic groups. Figure 6**,** Participation in Energy, provides the current state of the energy sector, with respect to the 2020 United States Census.

4.5.3 Interpreting Visualizations for Economic Structural Equity

While Figure 6 does not demonstrate significant differences in proportions for the five main demographic groups, the data does imply that there is a form of economic structural inequity in the energy sector workforce. In all sectors, the proportion of the Black and African-American demographic group and the Hispanic or Latino demographic group are lower than their corresponding representation in the United States Census. The most alarming statistic is the five percent difference between the Census data and the data provided in the renewable energy sector.

Renewable energy is a growing industry, due to the need of the energy transition needed to reach carbon neutrality by 2050.[7] The equitable growth of the renewable energy industry needs to be equitable to ensure policies and developments done that take into consideration all demographic groups and ensure a fair and just implementation of these systems. With the amount of jobs opening in the sector annually, equity can be reached if it is a priority.

Simultaneously, the fossil fuel industry is steadily declining, which will cause the loss of millions of jobs in the coal, oil, and natural gas industries.[3] The loss of these jobs aren't necessarily bad, as long as there is training and educational opportunities to provide current workers in the fossil fuel industry with the skills they need to successfully transition into a different career path. Ensuring that all of the demographics have equal access to resources and opportunities to transition will also be vital in determining the future of equity in the United States.

While the data visualized from this section can demonstrate a rather small issue in the inequity in the energy workforce, a deeper look into inequity amongst management positions, positions with higher pay, and opportunities to develop and move up the corporate ladder are likely to demonstrate larger amounts of inequity in the economic sector of structural equity.

4.5 Evaluating Structural Equity: Social Structural Equity

Evaluating the social subcategory of structural equity provides insight on the current structure of renewable energy with a focus on the social pillar of sustainability. The process of evaluating social structural equity focuses on the policies that will promote social equity. As mentioned in Section 3.3.2, social structural equity is hard to quantify, as are most aspects and elements that deal with measuring structural equity. The evaluation of social structural equity focuses on the programs and policies in place intended to minimize inequity and create justice in renewable energy. Similar to other aspects of this paper, the focus will be on federal policies and actions.

The majority of the federal policies and systems that are meant to address social energy inequity in the renewable energy sector are relatively new, as the Department of Energy's Office of Economic Impact and Diversity team will lead an initiative focused on accomplishing President Joe Biden's Justice40 Initiative, which is a plan to deliver forty percent of the overall benefits of climate investments to disadvantaged communities and inform equitable research, development, and deployment within the Department of Energy.[18] The recency of the policy makes it difficult to evaluate, as there is no data on plans and action items to address the achievement of Justice40.

The two other major federal policies to address social structural equity by the National Renewable Energy Laboratory (NREL) and the Department of Energy focus on addressing low income solar power implementation[16] and low income community energy solutions.[15] While these policies are new, the NREL policy is taking a systems thinking methodology of the policy as the policy includes information on challenges in implementation, methods of designing systems and programs for creating funding in a socially equitable manner, securing funding a detailed plan of their next steps. While the Low Income Community Energy Plans by the Department of Energy is not as comprehensive, the methodology used in its development and the resources listed on the website appear to focus on the future of creating social equity in renewable energy.

4.6 Evaluating Structural Equity: Environmental Structural Equity

Evaluating the environmental subcategory of structural equity provides insight on the current structure of renewable energy with a focus on the environmental pillar of sustainability. The process of evaluating environmental structural equity focuses on the harm caused by the current infrastructure and systems in the energy sector. Coupled with the data on green infrastructure in previous sections, there will be enough data to make reasonable conclusions on the current state of environmental structural equity in the United States.

4.6.1 Collecting Data for Environmental Structural Equity

According to the metrics stated in Section 3.3.3, the key data points to measure and determine the degree of environmental structural equity will involve looking at the pollution in impoverished and low-income communities. The main data points analyzed will be simplified into two sectors that focus on proportions: (1) the median income for a given zip code and (2) the concentration of pollutants, carbon dioxide, methane, and nitrous oxides. These two data points will provide insight to the degree of equity in an environmental lens.

The methodology to collect data for sector (1) median income by zip code is exactly the same as the one used in Section 4.3.1. For sector (2), the data extracted is directly from the Environmental Protection Agency (EPA) Power Profiler Tool.[17] By entering the zip codes from the first data point into their power profile Excel sheet, the concentrations of key contaminants such as carbon dioxide and methane were returned.

4.6.2 Interpretation & Evaluation of Data into Visualizations for Economic Structural Equity

Due to a similar data format and structure of participation in Section 4.2: Participation in Distributional Energy, it was determined that the best way to determine a relationship between pollutant concentration and median income, a scatter plot of pollutants carbon dioxide concentration in emissions in the units of pounds per megawatt hour vs median income and methane concentration in emissions in the units of pounds per megawatt hour vs median income would be adequate to determine a correlation and the level of environmental structural equity.

4.6.3 Interpreting Visualizations for Environmental Structural Equity

Based on the raw data and the graph, it appears as if the data provided from the Power Profiler tool is exclusively based on region as compared to the actual zip code number, itself. Due to the lack of data in this sector, it is difficult to make an assertion on the current state of environmental structural equity with respect to pollutants. The lack of significant data from Section 4.2 and this section leads to the assumption that the state of environmental structural equity is inconclusive. However, the abundance of articles and discussions regarding pollution and environmental injustice issues in the form of factories in low income, marginalized communities implies that there is work needed to be done in other sectors to create environmental equity.

5. Future Prospects & Conclusion

Overall, the data and results from the different components of equity in renewable energy indicate that the United States has not reached equity in the renewable energy sector. Despite this factor, there is reason to believe that the United States is on the right track towards addressing energy injustice and other issues that arise from and cause energy inequity. The lack of accessible data and the lack of data specifically tailored towards measuring energy equity indicates that energy justice and renewable energy equity are relatively new topics of interest and discussion. While there are some indicators on the federal and national level that imply energy equity, there are some concerning aspects in economic structural equity in the form of workforce development and procedural equity in the lack of policies and bills discussed to fix energy inequity and environmental justice issues.

The lack of awareness and academic writing on this issue is a cause for concern. The most important steps to create equity from the data collected are to prioritize energy equity on a federal level in the form of policies, actions, and economic support. Simultaneously, gauging interest in the energy sector for marginalized groups and communities are particularly important for creating a more equitable future. Lastly, the inclusion of local community leaders and an emphasis on supporting community leaders will help launch a wide variety of initiatives that will address renewable energy inequity.

Some possible sources of error and future improvements that could be made towards building upon this paper include examining and evaluating renewable energy equity on the local level in communities, measuring inequality with respect to gender inequality, LGBTQ+ representation, and the examination of the clean energy sector implementation in different geographical areas, while focusing on the urban, suburban, and rural areas.

There is opportunity for equity in renewable energy for all and by making decisions now, the United States will be successful in creating an equitable transition of energy, that will be more resilient and may be able to fix other issues and sectors of inequity in modern society.

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Appendix

Figure 1: 2019 Procedural Equity.

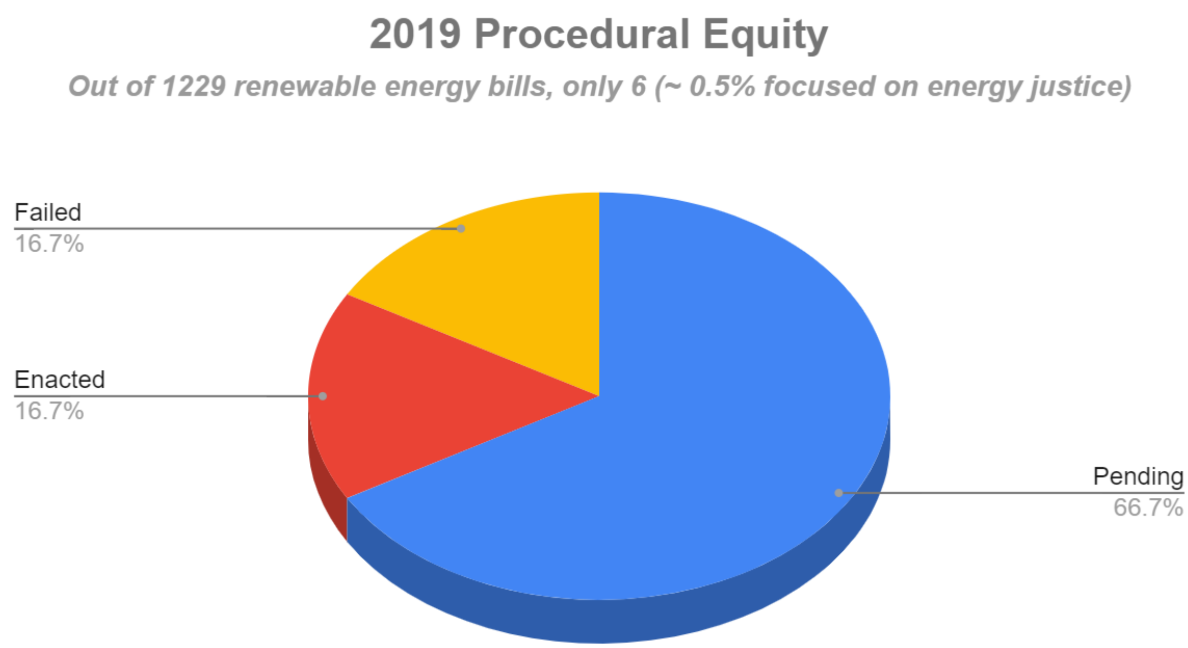

Figure 1: 2019 Procedural Equity. Data extracted from the National Conference of State Legislatures.

Figure 2: 2021 Procedural Equity

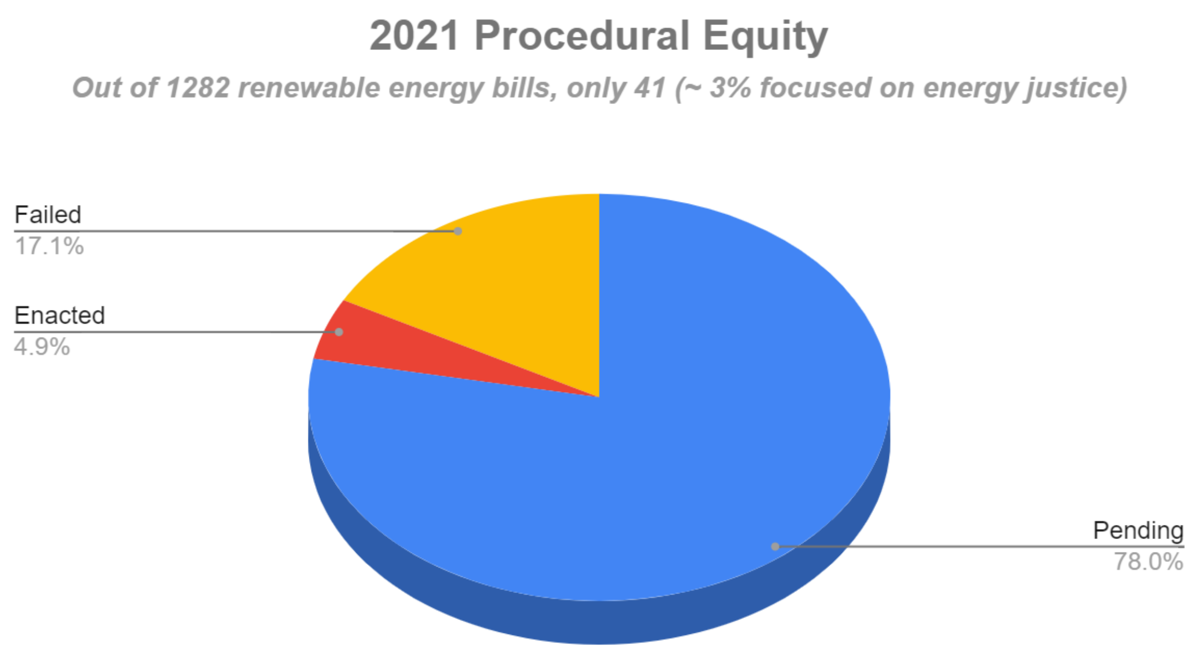

Figure 2: 2021 Procedural Equity. Data extracted from the National Conference of State Legislatures.

Figure 3: Annual Green Power Usage vs. Average Income

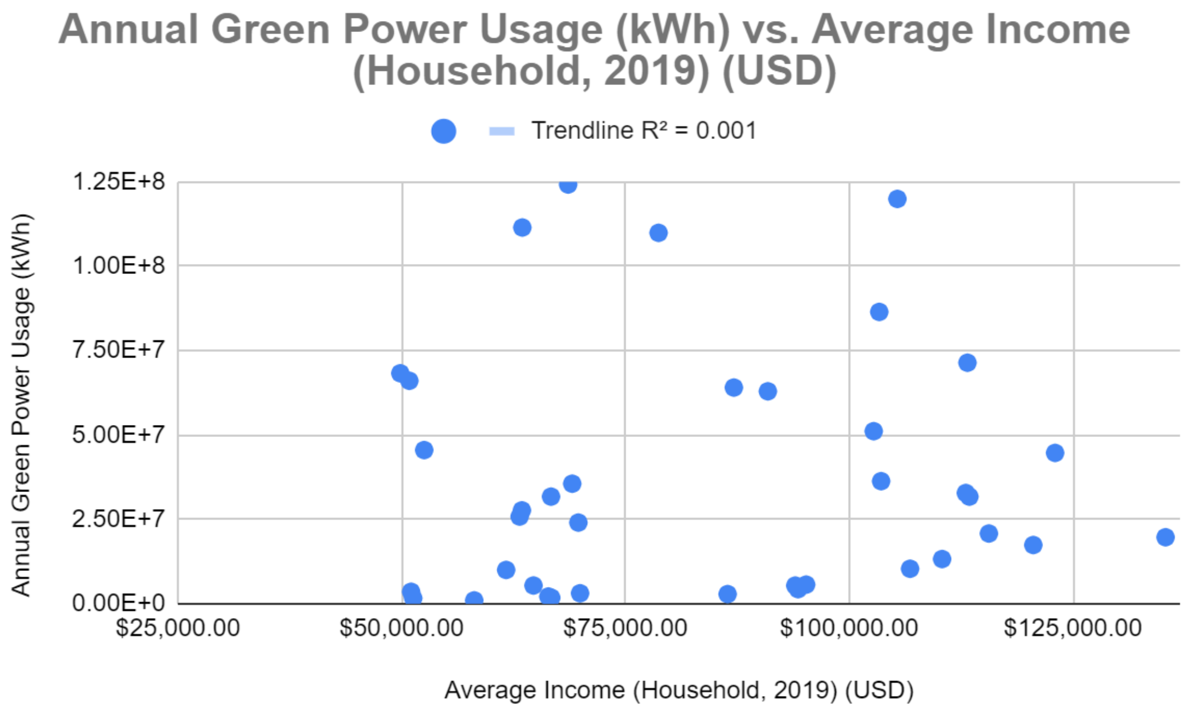

Figure 3: Annual Green Power Usage (kWh) vs. Average Income (Household, 2019) (USD). Data extracted from Data USA and the Environmental Protection Agency.

Figure 4: Green Power % of Total Electricity Use vs. Average Income

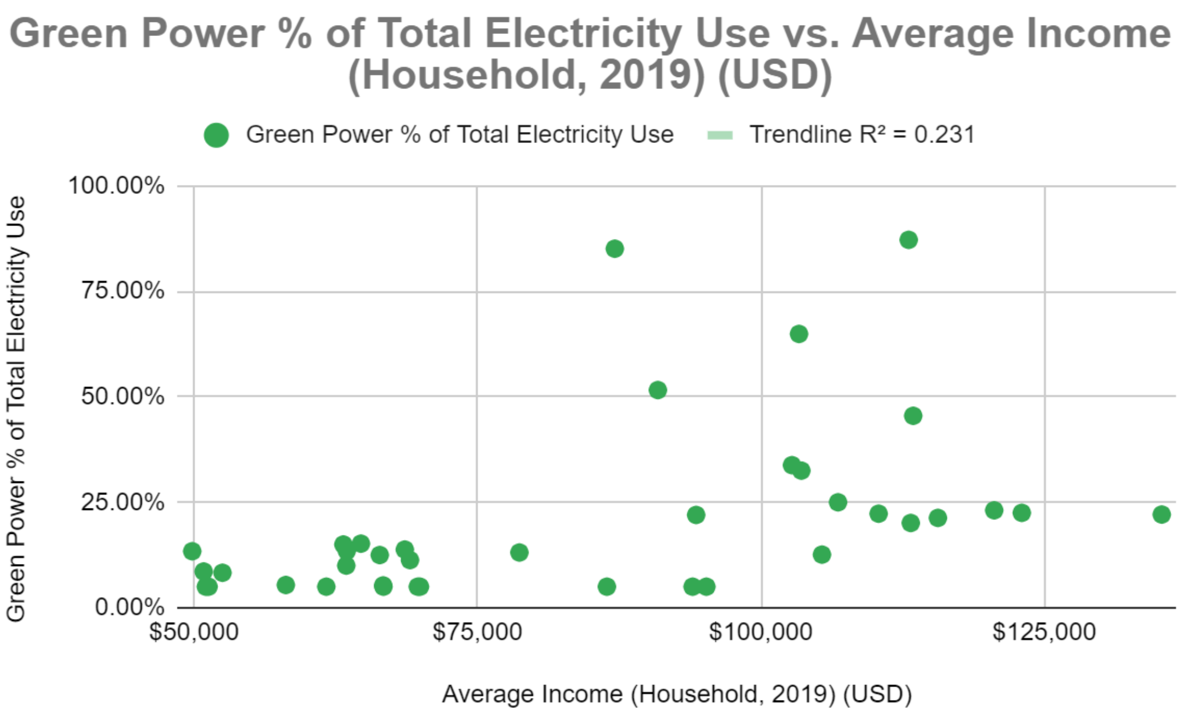

Figure 4: Green Power % of Total Electricity Use vs. Average Income (Household, 2019) (USD). Data extracted from Data USA and the Environmental Protection Agency.

Figure 5: Low-Income Energy Burden

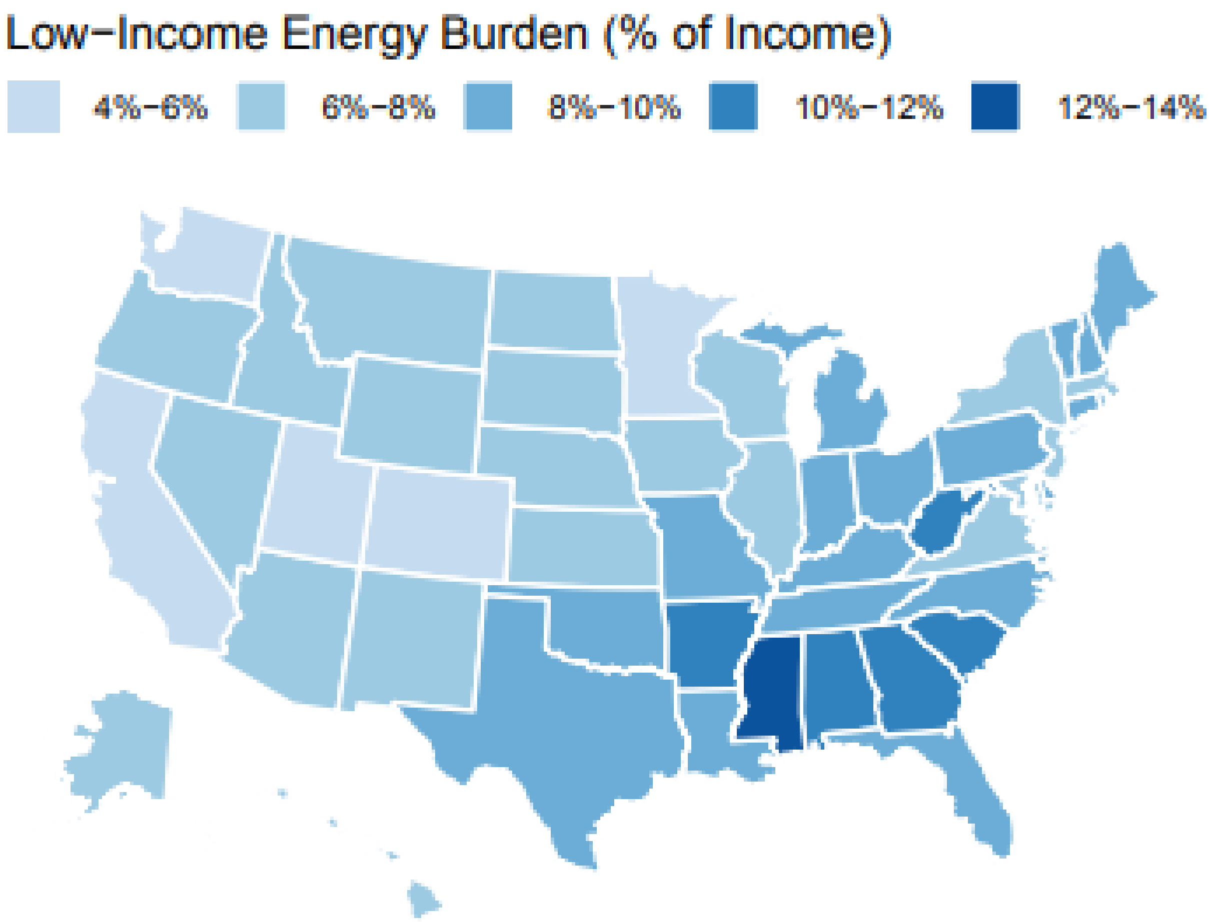

Figure 5: Low-Income Energy Burden (% of income) Figure comes from United States Department of Energy Office of Energy Efficiency & Renewable Energy.

Figure 6: Participation in Energy

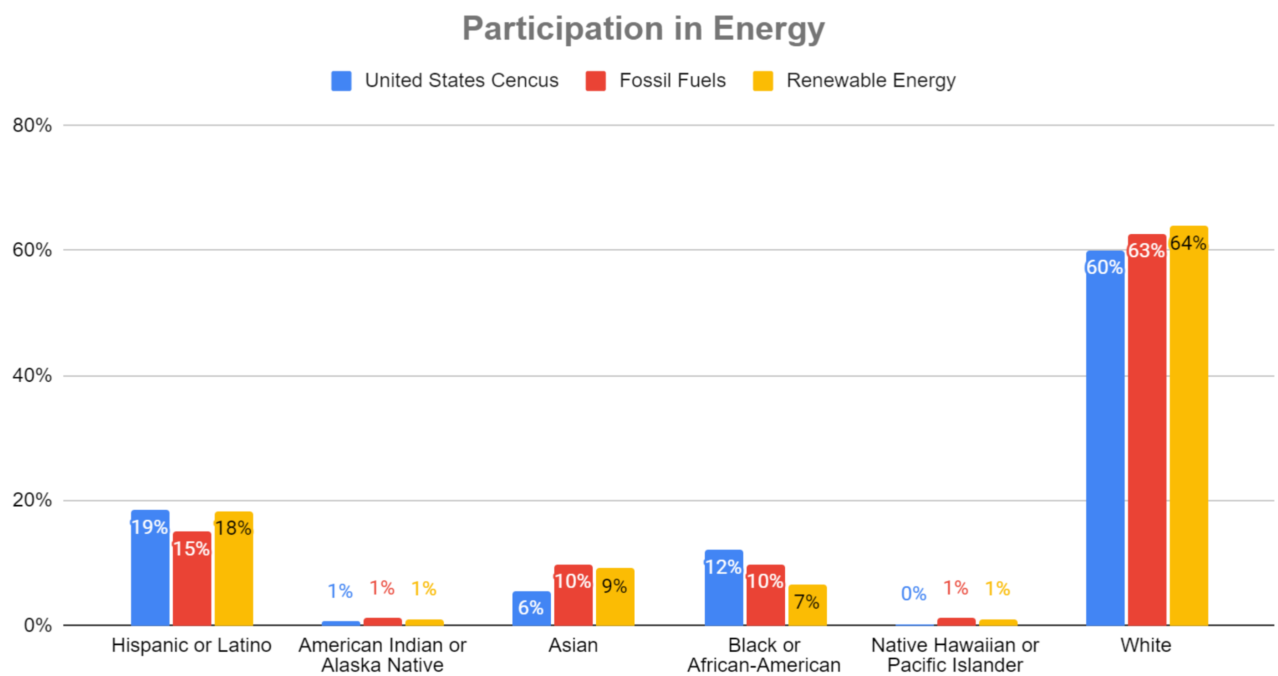

Figure 6: Participation in Energy. Data extracted from the 2020 United States Census and the 2019 United States Energy & Employment Report.

Figure 7: CO_2 vs. Median Income

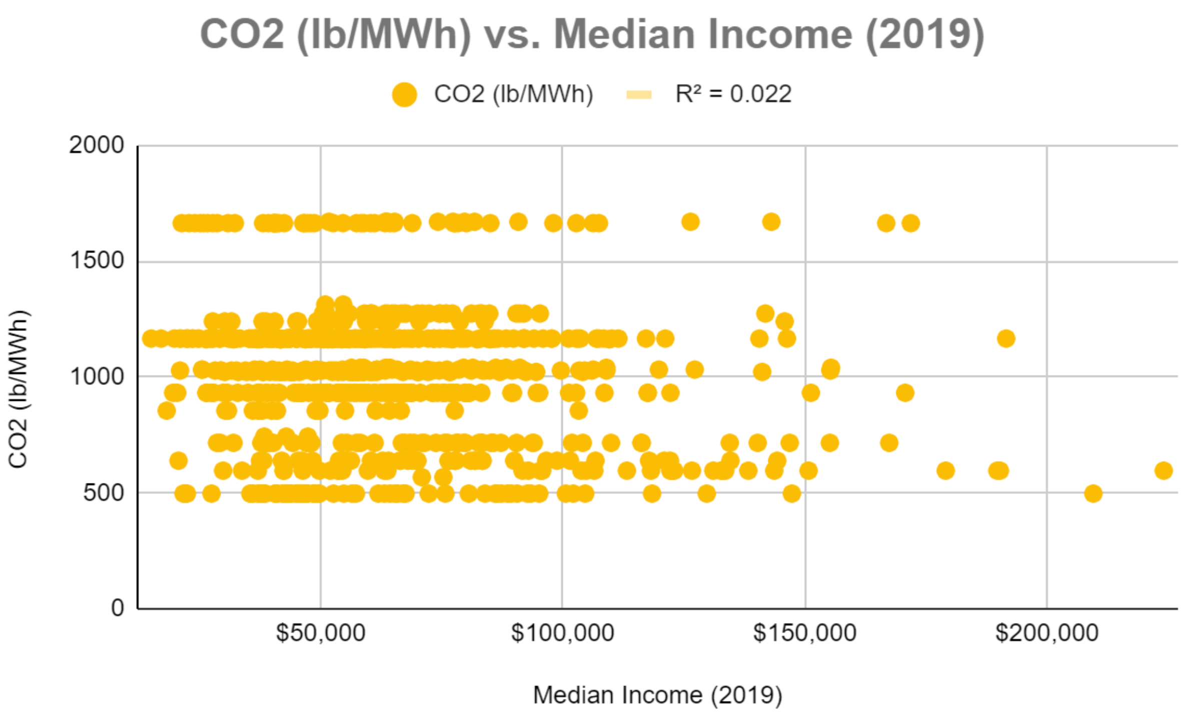

Figure 7: CO2 (lb/MWh) vs. Median Income (2019). Data extracted from Income by Zip Code and the Environmental Protection Agency Power Profiler Tool.

Figure 8: CH_4 vs. Median Income

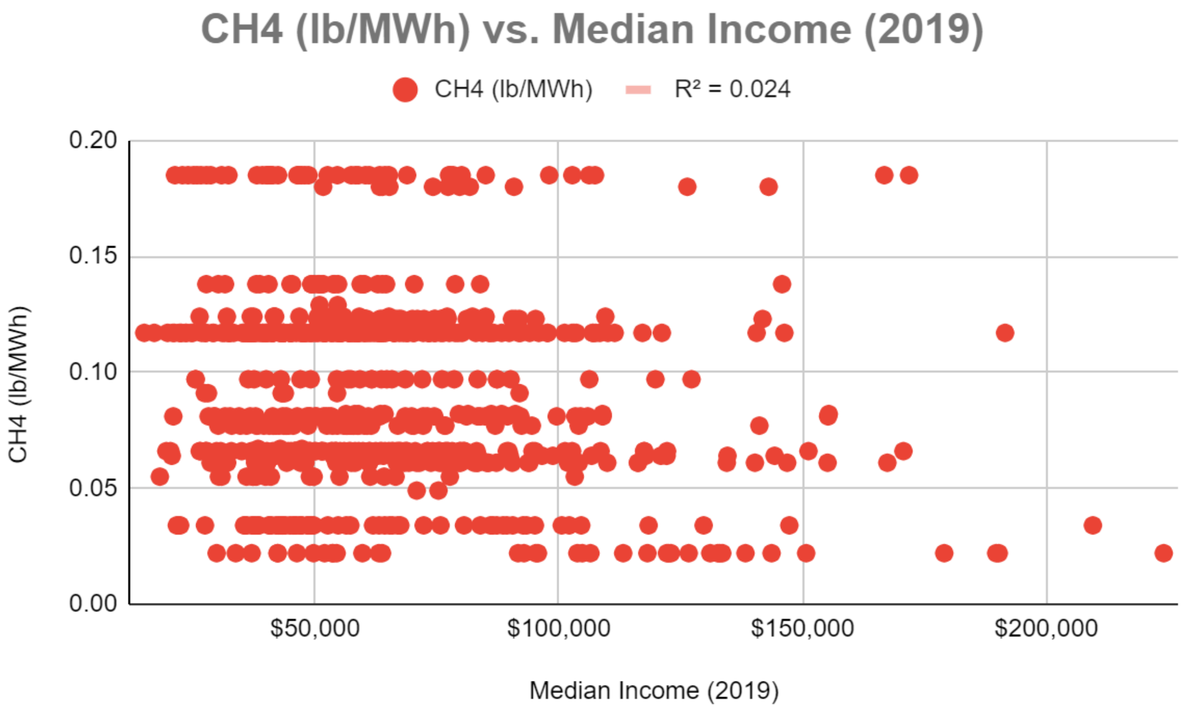

Figure 8: CH4 (lb/MWh) vs. Median Income (2019). Data extracted from Income by Zip Code and the Environmental Protection Agency Power Profiler Tool.

Tables

1. Table 1: Procedural Equity. See Procedural Equity tab on spreadsheet link attached below: https://docs.google.com/spreadsheets/d/1Pzr1IkGaWMqjLsWbAbnvF0ReUZlFr05MLUyqgS_j3OA/edit#gid=1042608749
2. Table 2: Participation. See Participation tab on spreadsheet link attached below: https://docs.google.com/spreadsheets/d/1Pzr1IkGaWMqjLsWbAbnvF0ReUZlFr05MLUyqgS_j3OA/edit#gid=1042608749
3. Table 3: Low Income 1. See Low Income tab on spreadsheet link attached below: https://docs.google.com/spreadsheets/d/1Pzr1IkGaWMqjLsWbAbnvF0ReUZlFr05MLUyqgS_j3OA/edit#gid=1042608749
4. Table 4: Low Income 2. See parameter tab on spreadsheet link attached below: https://docs.google.com/spreadsheets/d/1Pzr1IkGaWMqjLsWbAbnvF0ReUZlFr05MLUyqgS_j3OA/edit#gid=1042608749
5. Table 5: Workforce Development. See Workforce Development tab on spreadsheet link attached below: https://docs.google.com/spreadsheets/d/1Pzr1IkGaWMqjLsWbAbnvF0ReUZlFr05MLUyqgS_j3OA/edit#gid=1042608749
6. Table 5: Environmental Structural Equity. See Environmental Structural Equity tab on spreadsheet link attached below: https://docs.google.com/spreadsheets/d/1Pzr1IkGaWMqjLsWbAbnvF0ReUZlFr05MLUyqgS_j3OA/edit#gid=1042608749

Response to Peer Review Comments

Peer Review 1

The critique of the paper was very insightful and detailed and contributed some great components that were embedded in the final draft of this paper. The peer review also contributed to some topics that need to be further researched and addressed in regards to the future prospects of equity in renewable energy.

Compared to the first draft, the final paper has several sections that evaluate the current state of each metric. These can be found in Section 4: Evaluating Metrics. The evaluation process involved explaining the methodology in which data was collected and extracted, if that was done for that equity metric, followed by an explanation and interpretation of data into a visualization, and then finally an evaluation based on the data presented throughout the paper. While each section provides a comment on what needs to be improved, the main areas of focus that need to be addressed and improved are discussed in detail in Section 5: Conclusions & Future Prospects.

As for a section on recent news and development/legislation regarding equity in renewable energy, this was deemed to be difficult due to the lack of data available for review that discusses the past of equity in renewable energy. It should also be noted that renewable energy is a relatively new sector that is still rapidly growing and exponentially developing over time. Due to this, there are not that many data points from its origin regarding legislation. See Section 4.1: Evaluating Procedural Equity for more details.

Finally, the connection to the importance of equity was mentioned in the introduction section and the conclusion and future prospects section. All other points mentioned in the peer review have been addressed in the final paper.

Peer Review 2

Similar to the first peer review, Peer Review 2 also provided some very valid and insightful points. As for meeting the guidelines for the paper, the final draft is 20 pages in length with all fonts being Times New Roman font size 11, with the exception of code blocks and section headers.

This peer review also mentioned that the first draft was far from complete, which is very true. Compared to the first draft, Section 1: Introduction was further developed, Section 4: Evaluation of Metrics, and Section 5: Conclusion & Future Prospects were added to explain the source of data, the interpretation of the data into different visualizations, and finally, into making conclusions.

The connections between equity and renewable energy and the importance are mentioned in Sections 4: Evaluating Metrics and Section 5: Conclusions and Future Prospects. While the evaluation section may not depict a clear connection, the conclusion and introduction sections highly emphasize these points.