Emissions and Perceptions of Climate Change

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Introduction

In the great pursuit of mitigating climate change, countries have differed in their strategies and successes. Denmark has one of the most ambitious mitigation plans in the world pledging to cut 70% of its emissions by 2030.[1] As other countries trail behind, illuminating how Denmark is successfully reducing its emissions is pertinent for other countries. Although reducing emissions involves extensive effort from multiple sectors, the citizens also greatly determine the success of mitigation plans.[2] What determines people's perceptions and willingness to decrease their own emissions, is therefore important for countries to understand. To delve into this question I will anaylze data from two global surveys on climate perceptions along with green house gas emissions and the reduction rate of countries. Special emphasis will be on comparing Denmark due to the country's success, and the United States, due to it's world's leading production of oil and natural gas.[3]

This data analysis will consist of two sections: the greenhouse gas emissions of the U.S.and Denmark, and the climate change perceptions of their citizens.

In the emissions section Denmark's and the United State's per capita emissions and the rate of decrease will both be compared.I hypothesize that Denmark will have less emissions and a faster emission reduction rate than the United States, because the U. S. had the highest cumulative greenhouse gas emissions from 850-2021 whereas Denmark has one of the most ambitious emission reduction plans in the world.[4]The emissions data data can be found here: https://www.climatewatchdata.org/ghg-emissions?end_year=2019&start_year=1990

The second section will include an analysis of several questions regarding climate change for both the U.S. and Denmark. These will include what Americans and Danes believe caused climate change, how worried they are about it, how big of a threat they believe climate change is in the next 20 years, and if they believe fossil fuel usage should decrease, increase, or stay the same. I hypothesize Denmark will have a significantly higher percentage of people who believe climate change is human caused than the U.S, because Denmark hosted COP15, which sparked national social media attention on climate change, exposing many Danes to the concept.[5] I further hypothesize that more Danes will be very worried about climate change and see it as an extreme threat than U. S. citizens, because climate change is uniformly depicted in Danish media as a problem, but it is not uniformly depicted in this manner in the U.S.[4] Lastly, I hypothesize that more Danes will answer that fossil fuel usage should be reduced than Americans, due to the aforementioned reasons.[1,3,4] The facebook data used for this section can be found here:https://data.humdata.org/dataset/climate-change-opinion-survey.

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[1]Etsy, D. C., "Why Denmark Wants to Be a 'Frontrunner' in the Fight Against Climate Change." Yale School of the Environment.2021.

[2]Weber, E. U., "What Shapes perceptions of climate change?," WIRES Climate Change.2010

[3]Gross, S., "The United States can take climate change seriously while leading the world in oil and gas production." Policy 2022 Brookings. 2022.

[4]Evans, S., "Analysis: Which countries are historically responsible for climate change?." Carbon Brief, 2021.

[5]Gunster, Shane. "Covering Copenhagen: Climate Change in BS Media." Canadian Journal of Communication 36, no.3 (Nov 2011): 477-502. DOI: 10.22230/cjc.2011v36n3a2367

Preparing R

```r
rm(list=ls())
library(tidyverse)
library(here)
library(ggfortify)
library(forecast)
library(gridExtra)
```

Statistcal Analysis and Results

Statistical analysis will consist of the aforementioned two sections.

Climate Change Emissions of Countries

Pulling in the corrected Emissions data. For the raw data see the raw data folder on github. Please also see the metadata txt files per each data set in the Data for the Code folder and the metadata folder.

Lets first view the emissions of Denmark and the United States.

Reading in the Data

```r
emissions<-read.csv(here("Data for the Code", "Corrected_Data_sets",
                "emissions_corrected_US_Denmark.csv"), stringsAsFactors = TRUE)
```

Lets turn the date column into date data using base R.
To do that we need to put in the day and the month using paste.

```r
emissions$year<-paste0("01-01-", emissions$year)
```

Now tell R the year column are dates so we can better perform statistical analysis.

```r
emissions$year<-as.Date(emissions$year, format="%d-%m-%Y")
#format tells R the dates are just a four digit year, a two digit year
#is %y, origin informs R where it starts.
# must do the - in the %d- because the dates are entered with a -.
```

Now when running statistical tests R will know the data are dates.

Creating the figure   Lets see the emissions of Denmark and the United States from 1990 to 2019.

```r
ggplot(emissions, aes(year, emissions, colour= country, group=country)) +
  geom_line() +
  geom_point(aes(colour=country))+ theme_bw() #colour colors by country,
```
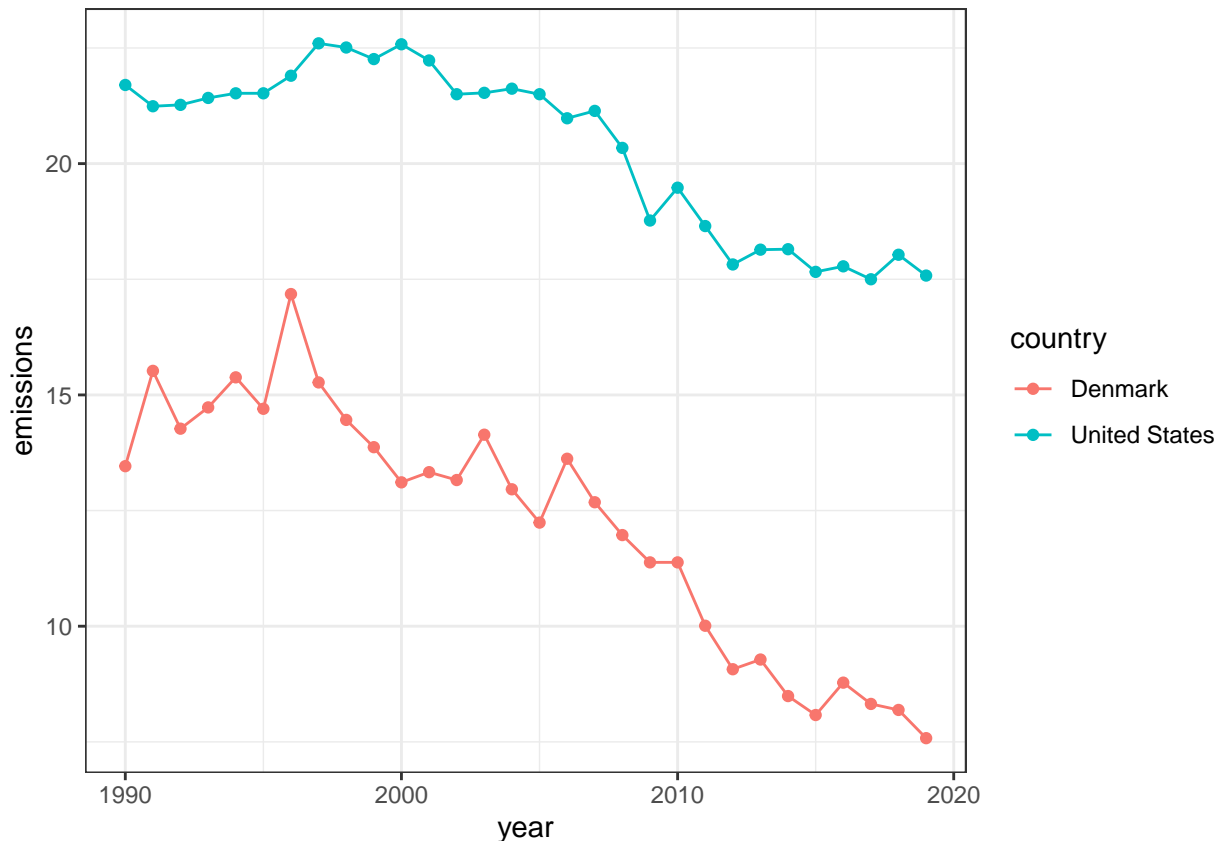
```
#and group tells R to group the points by country so geom_line will draw
#lines connecting the data by country.
```

Figure 1. Per capita greenhouse gass emissions od Denmark and the U.S.from 1990 to 2019.

Already it is apparent that Denmark produces less GHG emissions per capita each year than the United States. Both countries have been decreasing their emissions since 1990, but Denmark seems to have a greater rate of decrease in emissions, especially since 2006, than the United States.

Running a paired t test will let us compare the rate of decrease in emissions of both these countries.

Running the Statistical Test

```
t.test(emissions~country, data=emissions, paired=TRUE)
#like running a t test, but tell r the data is paired.
```

```
##
##  Paired t-test
##
## data:  emissions by country
## t = -35.063, df = 29, p-value < 2.2e-16
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -8.618685 -7.668649
## sample estimates:
## mean of the differences
##                -8.143667
```

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The p-value is very less than 2.2*10^-16, much less than 0.05, so we can reject our Null hypothesis. Denmark does have significantly less GHG emissions per capita than the United States.

What about the Rate of Decrease?

Calculating rate

```
emissions$rate<-NA
denmark_rate<- emissions %>% filter(country=="Denmark")
den_rate<- diff(denmark_rate$emissions) # subtracts n by n-1 to get rate.
denmark_rate$rate[2:30]<-den_rate
denmark_rate<-denmark_rate[2:30,]

emissions$rate<-NA
usa_rate<- emissions %>% filter(country=="United States")
us_rate<- diff(usa_rate$emissions)
usa_rate$rate[2:30]<-us_rate
usa_rate<-usa_rate[2:30,]

emissions_rate<- rbind(usa_rate, denmark_rate)
emissions_rate_2010<- emissions_rate %>% filter(emissions_rate$year>="2005-01-01")
```

Lets look at the rate of Denmark and the United States.
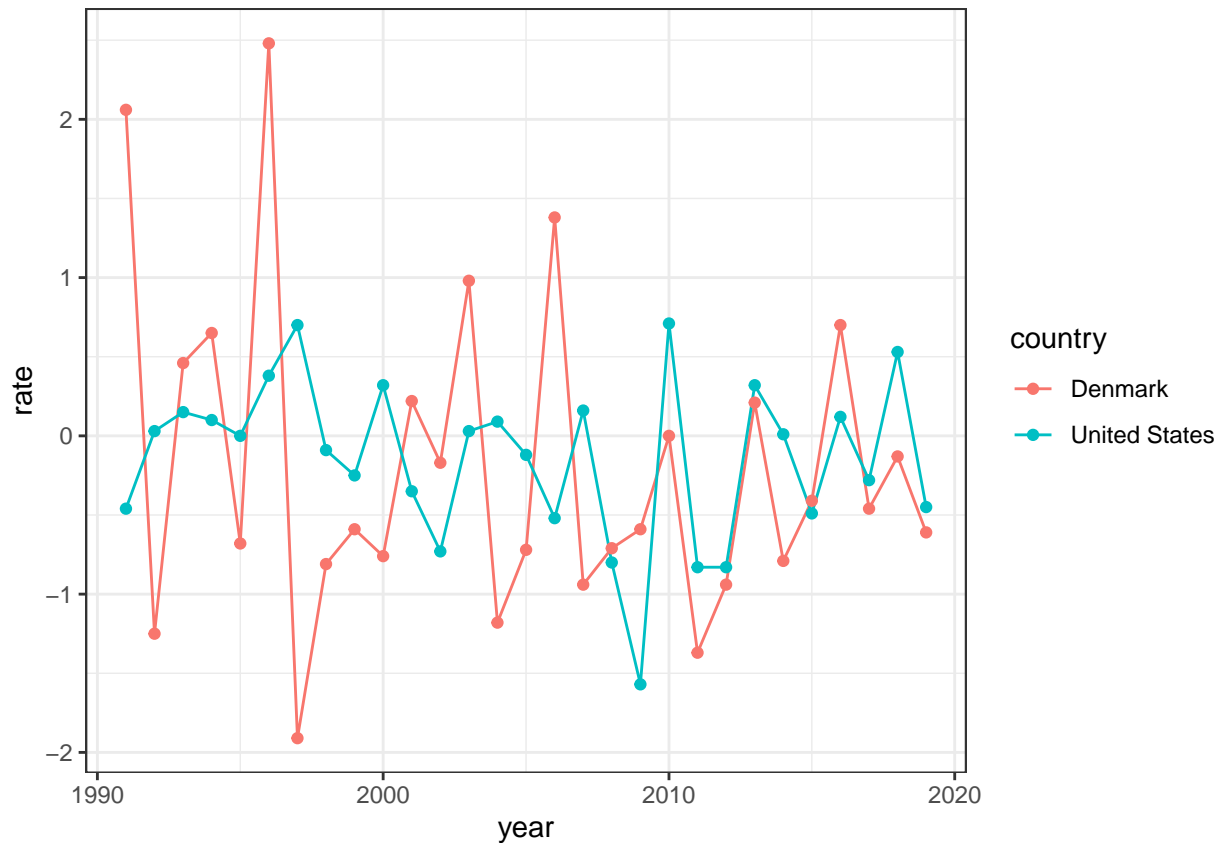
```
ggplot(emissions_rate, aes(year, rate, colour= country, group=country)) +
  geom_line() +
  geom_point(aes(colour=country))+ theme_bw() #colour colors by country,
```

Figure 2. The rate of per capita greenhouse gas emissions for Denmark and the U.S. from 1990 to 2019.

There us alot of added noise, making it difficult to see overal trends. Lets view the rate data smoothed over.

```
#colour colors by country, and group tells R to
#group the points by country so geom_line will draw lines connecting the
#data by country.
ggplot(emissions_rate, aes(year, rate, colour= country, group=country)) +
  geom_smooth() + theme_bw()
```
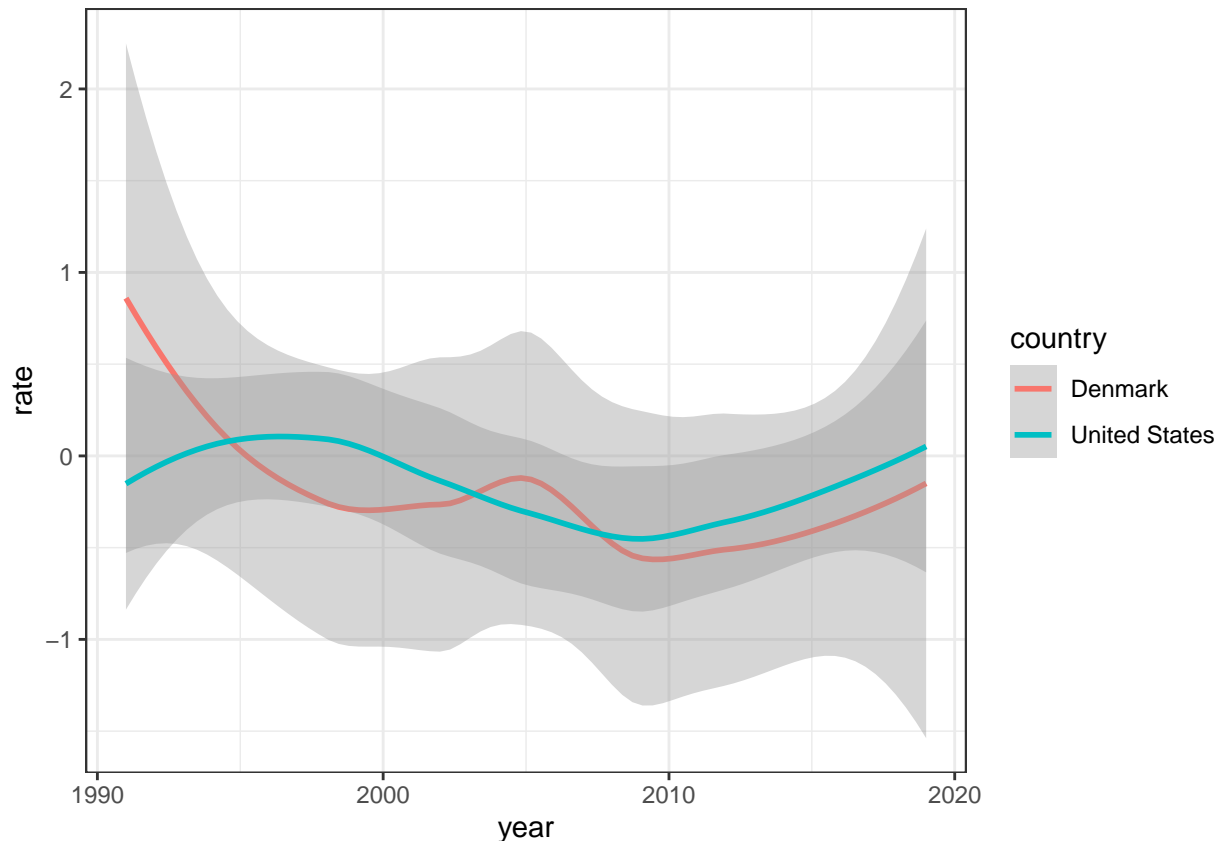
Figure 3. The smoothed over rate of per capita greenhouse gas emissions for Denmark and the U.S. from 1990 to 2019.

Denmark's rate is more variable over time, but it stays below 0, after 1995, whereas the US is not consistently below zero until 2000. It also goes above zero at 1990. Therefore, Denmark started decreasing its emissions five years prior to the U.S. and the U.S.'s emissions might be increasing again in 2019. Given Denmark has a lower rate from 2010-2019, it may have a significantly lower rate than the U.S. Lets run a statistical test to verify.

Running the Statistical Test

Lets run a paired t-test to see if this is significant.

```
#complete.cases means just use the ones without NAs
t.test(rate~country, data=emissions_rate, paired=TRUE)
```

```
##
##  Paired t-test
##
## data:  rate by country
## t = -0.2994, df = 28, p-value = 0.7668
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.4759099  0.3545306
## sample estimates:
## mean of the differences
##              -0.06068966
```

Looking at the entire range from 1990-2019, the p value is 0.7668, so we must accept the Null hypothesiss. There is no significant difference in rate between Denmark and the U.S. Lets look at 2010-2019 given the differences in the functions listed above.

```
t.test(rate~country, data=emissions_rate_2010, paired=TRUE)
```

```
##
##  Paired t-test
##
## data:  rate by country
## t = -1.9483, df = 9, p-value = 0.08319
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.56403995  0.04203995
## sample estimates:
## mean of the differences
##                  -0.261
```

The p value is smaller at 0.083, however it is still not signifciant. So, we must accept the Null hypothesis. There is no significant difference in rate between Denmark and the United States.

Conclusion for Section One

The United States emits significantly more greenhouse gases per capita than Denmark, but there was no significant difference in how fast both countries decreased their emissions from 1990-2019.

Now lets look at some examples that may explain why Denmark emits less greenhouse gases per capita.

Perceptions of Climate Change

Reading in the data:

```
survey<- read.csv(here("Data for the Code", "Corrected_Data_sets",
                       "final_ccos_US_Denmark.csv"), stringsAsFactors=TRUE )
```

Though more people may have been interviewed in one country than the other, the survey data is in percent, as in the percentage out of the whole who chose that option. We can double check to ensure the recorded numbers equals 100 per country per survey question.

Lets check with the 'beliefs question' which is the first question we will analyze to ensure Denmark and the U.S. are comparable despite size differences.

```
#Parsing out just the survey answers regarding climate change beliefs
beliefs<- survey %>% filter(survey$question=="Ques__Climate_beliefs")

#Resetting the levels
beliefs$response<-factor(beliefs$response)
levels(beliefs$response)
```

```
## [1] "Caused about equally by human activities and natural changes"
## [2] "Caused mostly by human activities"
## [3] "Caused mostly by natural changes in the environment"
## [4] "None of the above because climate change isn't happening"
## [5] "Other"
## [6] "Refused"
```

```
total<- beliefs %>% group_by(Country) %>% summarise(total=sum(Number))
total
```

```
## # A tibble: 2 x 2
##   Country        total
##   <fct>          <dbl>
## 1 Denmark         100.
## 2 United.States   100.
```

Beliefs of Climate Change   Lets first see what Danes and Americans believe caused climate. The options to choose from were: caused mostly by humans, caused by natural change in the environment, caused by both, and climate change is not happening.

```
# Making the graph
ggplot(beliefs, aes(response,Number, fill=Country))+
  geom_bar(stat = 'identity', position = 'dodge') +
 labs(title="Cause of Climate Change", x="Response to Survey Question",
      y="Percent") + # titling and renaming x and y axis labels
  coord_flip()+
  theme_bw()
```
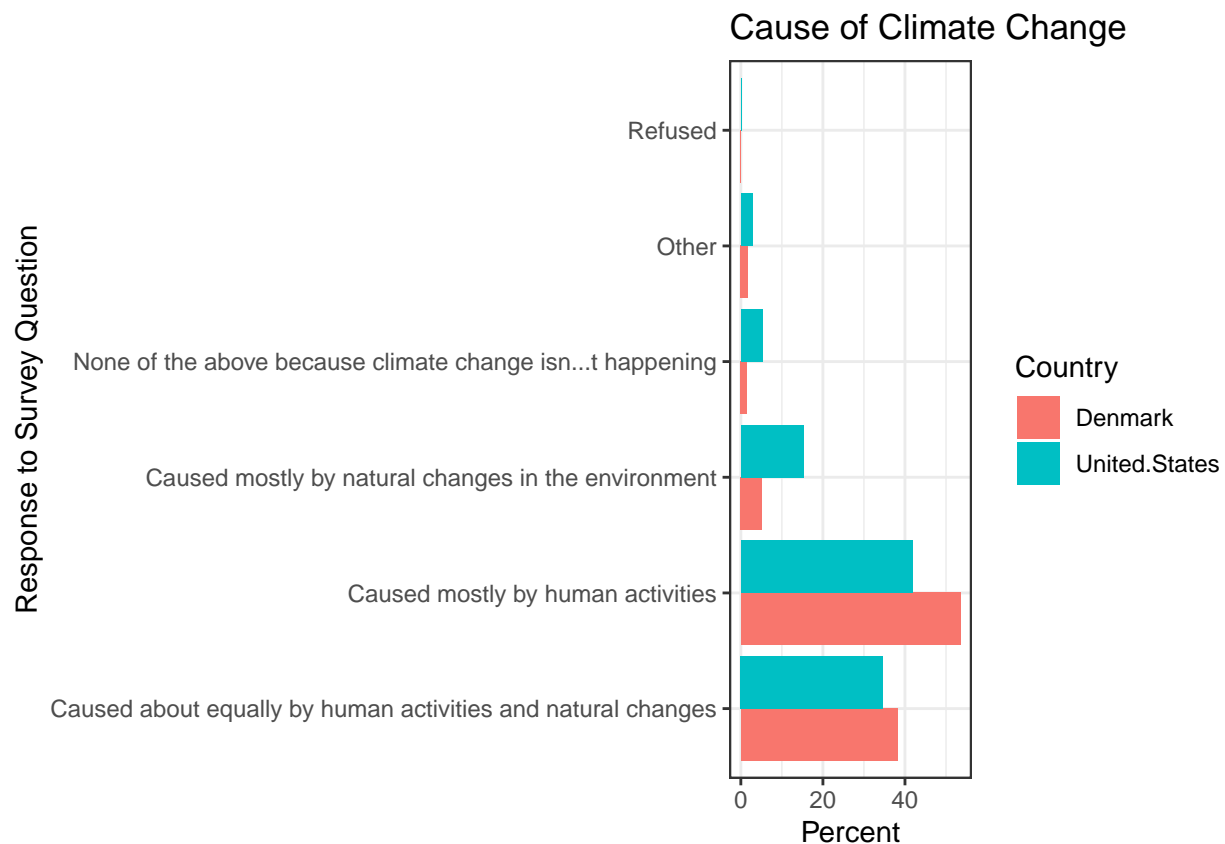

Figure 4. What Danes and Americans believe caused climate change. Responses are in percent of the total surveyed.

More Americans believe that climate change is not happening or that it is caused by natural changes than Danes. More Danes believe it is caused by human activities. However, more Danes than Americans think it is cause equally by both.

To get a better sense of the of which country answeres were more beneficial for combating climate change, lets look at a diverging bar graph. In this graph answers that increase our chances of combating climate change, in this case believing that climate change is caused by human activity, is made positive and answers that decrease our chances of combating climate change, in this case all other answers, are made negative. Due to the small percentage of people who refused, those will be removed from the diverging bar graph, so it is more visually appealing.

```
beliefs_diverging <- beliefs %>% filter(response!="Refused") %>%
  mutate(Number=if_else(response %in%
                    c("Caused mostly by human activities"), Number, -Number))
#all the percentages in the response column that did not
#answer "caused mostly by human activities"  will have a - put in front.
```

```
beliefs_diverging_Order<-beliefs_diverging %>%
  mutate(response=fct_relevel(response,
  "Caused about equally by human activities and natural changes",
  "Other", "Caused mostly by natural changes in the environment",
  "None of the above because climate change isn't happening",
  "Caused mostly by human activities"), response=fct_rev(response))
```

```
#first line below takes the Number column rounds it up,
#takes the absolute value of it and adds a % for the labels on the graph.
beliefs_diverging_Order<- beliefs_diverging_Order %>%
  mutate(percent=paste0(round(abs(Number), digits=0), "%"))

beliefs_divering<-ggplot(beliefs_diverging_Order,
                        aes(x=Country, y=Number, fill= response)) +
  geom_col()+ #also makes a bar graph
  geom_text(aes(label=percent), position=position_stack(vjust = 0.5),
            color="white", fontface="bold")+
  #stack stacks them, fontface bolds  the numbers in the bargraphs
  coord_flip()+
  scale_x_discrete()+

  #reorganizes the labels and color them
  scale_fill_manual(breaks=c("None of the above because climate change isn't happening",
  "Caused mostly by natural changes in the environment", "Other",
  "Caused about equally by human activities and natural changes",
  "Caused mostly by human activities"),
  values=c(
    "None of the above because climate change isn't happening"="darkorange4",
    "Caused mostly by natural changes in the environment" = "darkorange3",
    "Other" = "darkorange",
    "Caused about equally by human activities and natural changes"= "goldenrod1",
    "Caused mostly by human activities" = "deepskyblue"
  ))+

  labs(title="What do you Think Caused Climate Change", x=NULL, fill=NULL)+
 theme_minimal()+
  theme(axis.text.x=element_blank(), axis.title.x=element_blank(),
panel.grid=element_blank(),
legend.position="top")

beliefs_divering
```
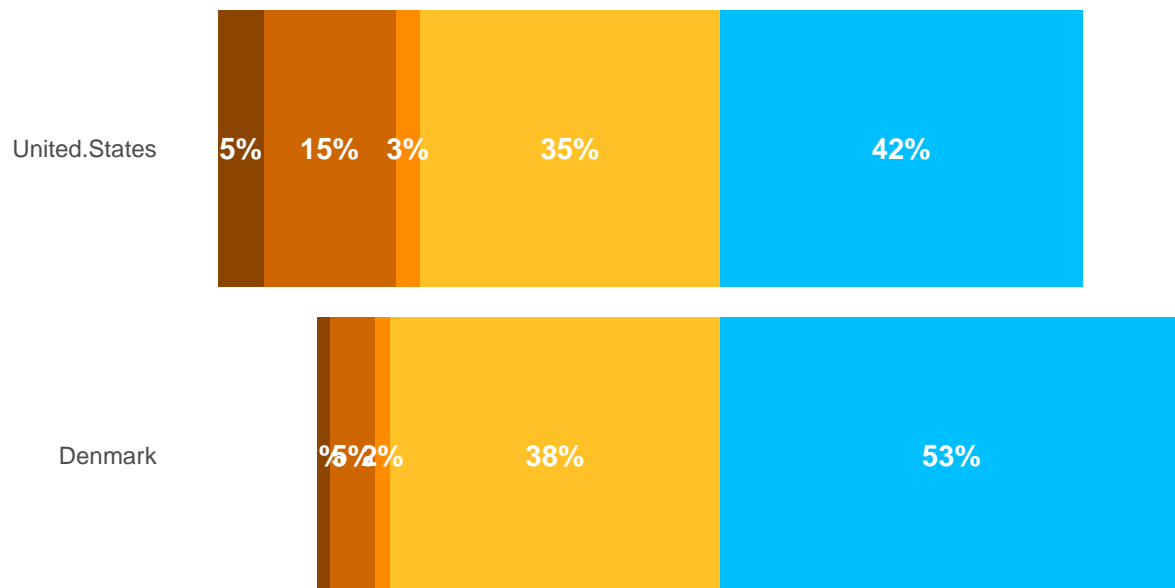
What do you Think Caused Climate Change

```
ggsave("beliefs_diverging.png")
```

Figure 4. Diverging Bar graph of what Danes and Americans believe caused climate change. Responses are in percent of the total surveyed.Darker orange is a more anti climate change answer, wherease blue is a climate activist answer.

For a easier to read figure please see the image saved in the code folder.

The diverging bar graph shows that most of the Danes surveyed believe climate change is human caused, whereas more Americans thought it was a mix of human and natural causes or that climate change is not happening.

Lets run a statistical test to see if Danes believe climate change is human caused significantly more than Americans.

Running the Statistical Test

We can put our data into two categories: those that believe climate change is human caused, and all other answers. This way we can run a chi-squared test and see if if it is significant.

first must convert percents to numbers by multiplying the percents times the total number of respondents to that question per country.

Given the diverging bar graph and chi squared test code chunks are virtually the same as above, they are not shown in the pdf version henceforth.

```
## `summarise()` has grouped output by 'Country'. You can override using the
## `.groups` argument.
```

```
##            grouped_answer
## Country         bad good
##   Denmark        511  589
##   United.States 1793 1295

##
##  Pearson's Chi-squared test with Yates' continuity correction
##
## data:  beliefs.mat
## X-squared = 43.699, df = 1, p-value = 3.829e-11
```

The p values is 3.829*10^-11, which is much less than 95%, so I can reject the Null hypothesis. Significantly more Danes think climate change is caused by humans verses other sources than Americans.

Level of worriedness about Climate Changed

In this survey question people were asked how worried they are about climate change. There are three options, very worried, somewhat worried, not very worried, not at all worried, and refused.

```
worry<- survey %>% filter(survey$question=="Ques__climate_worry")
```
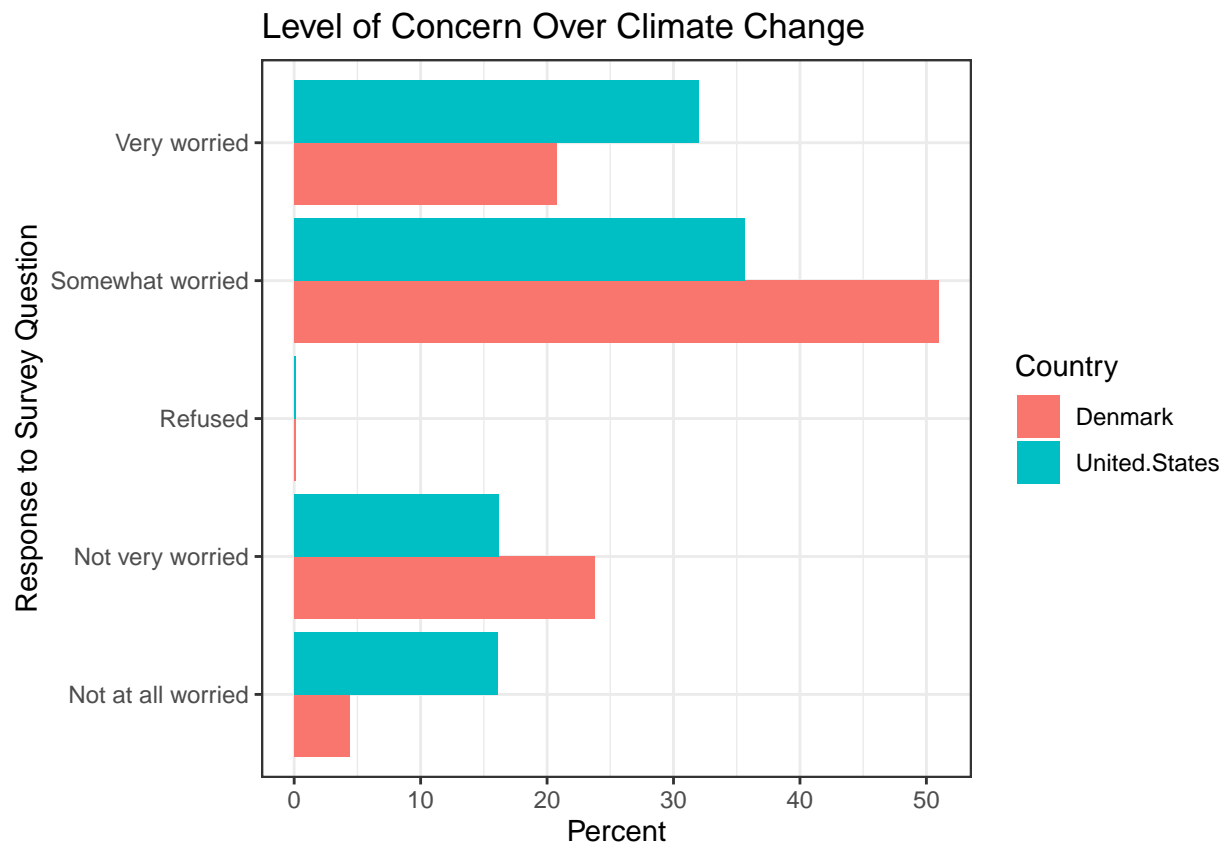

Figure 5. Bar graph of the Level of Concern over climate change of both Danes and Americans. Response is in percentage of the total surveyed.

32% of Americans are very worried about climate change, whereas only 21% of Danes are. But 52% of Danes are somewhat worried at only 36% are. To better visualize this lets look at a diverging bar graph.

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Given the small number of people who answered, refused, it will be left out for clairty of the diverging bar graph.
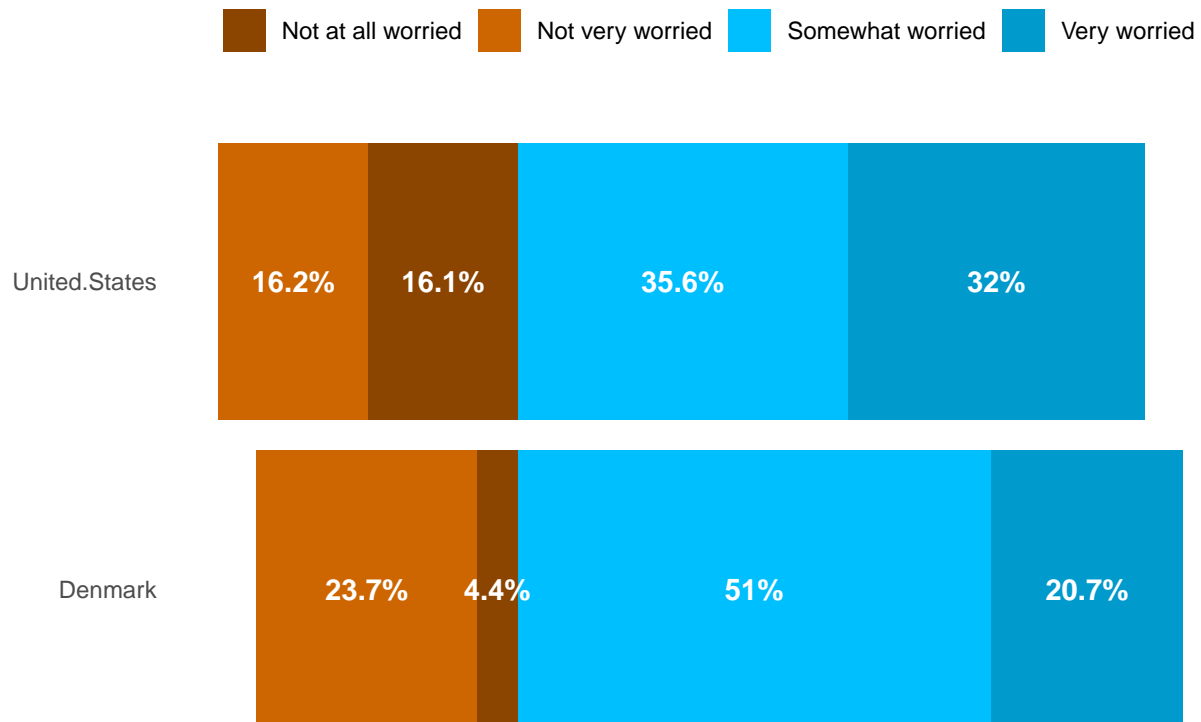

Figure 6. Diverging Bar Graph the Level of Concern over climate change of both Danes and Americans. Response is in percentage of the total surveyed.

We can see that most Danes are somewhat worried, with the smallest percentage being not worried at all. Most Americans are also somewhat worried, though the percentage is smaller compared to Denmark (51% to 35.6%). More Americans however are very worried, and more Americans are not at all worried than Danes. Based on the diverging bar graph, there is a slight difference between countries, suggesting Danes are more worried than Americans. A statistical test is needed to see if this is a significant difference.

Lets do a statistical test to verify.

Chi-square test.

Very and somewhat worried will be grouped together and not at all worried and not very worried will be grouped together.

first must convert percents to numbers by multiplying the percents times the total number of respondents to that question per country.

```
## `summarise()` has grouped output by 'Country'. You can override using the
## `.groups` argument.

##                 grouped_answer
## Country           not worried
##    Denmark        310     789
```

```
##    United.States 1000     2093
##
##  Pearson's Chi-squared test with Yates' continuity correction
##
## data:  worry.mat
## X-squared = 6.2273, df = 1, p-value = 0.01258
```

the p-value is 0.01258, which is less than 0.05. So, we can reject the Null hypothesis. Danes are more worried about climate change than Americans.

Is Climate Change a Big Threat

In this survey question people were asked whether or not climate change is a big threat within the next 20 years. The options were very serious threat, somewhat serious, not a threat at all, or I do not know.

parsing the data

```
threat<- survey %>% filter(survey$question=="Ques__threat_20_years")
```
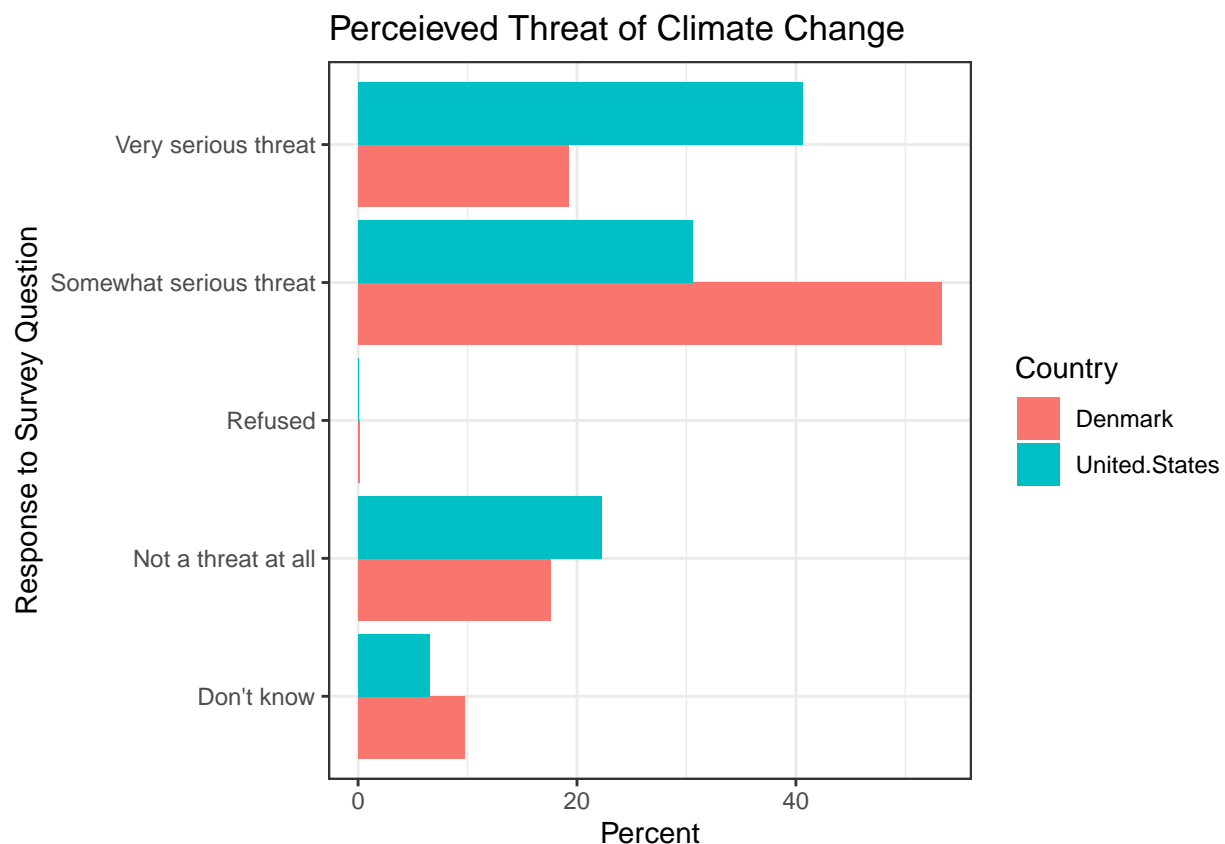

Figure 7. Bar graph of the perceieved threat of climate change of Danes and Americans. Response is in percentage of the total surveyed.

More Americans than Danes think that climate change is a very serious threat, but more Danes think it is a somewhat serious threat than Americans. More Americans also think that climate change is not a threat at all than Danes. Lets view a diverging bar graph.

Given the small number of people who answered, refused, it will be left out for clairty of the diverging bar graph.

In the Next 20 Years How Much of a Threat is Climate Change?

Not a threat at all   Don't know   Somewhat serious threat   Very serious threat

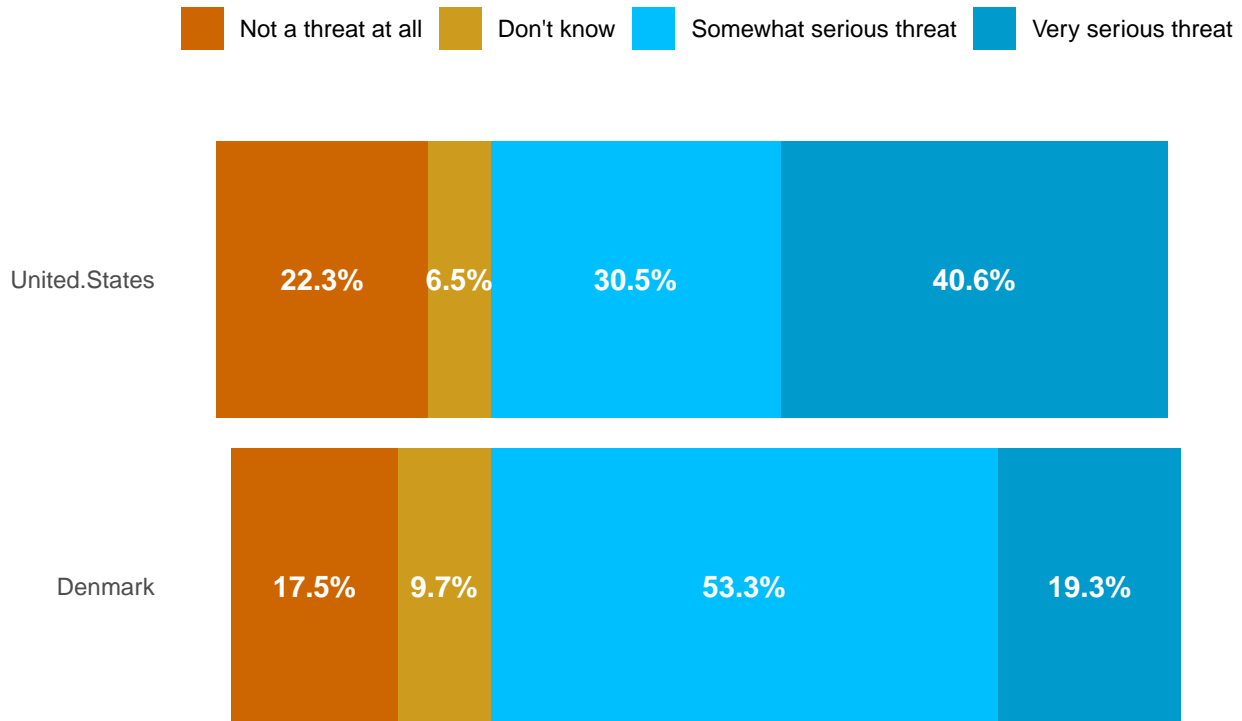|				
United.States	22.3%	6.5%	30.5%	40.6%
Denmark	17.5%	9.7%	53.3%	19.3%

Figure 8. Diverging bar graph of the perceived threat of climate change of Danes and Americans. Response is in percentage of the total surveyed.

We can see that most Danes, 53%, think climate change is a somewhat serious threat, wherease most Americans, 40.6%, think it is a very serious threat. Only 17.5% of Danes think that it is not a threat at all, compared to the 22.3% of Americans that think that. There is a small shift in Dane's bars leaning right, suggesting they think climate change is a more serious threat than Americans. Lets see if it is significant with a statistical test.

Lets do a statistical test to verify.

first must convert percents to numbers by multiplying the percents times the total number of respondents to that question per country.

```
## `summarise()` has grouped output by 'Country'. You can override using the
## `.groups` argument.
```

```
threat.mat<-xtabs(grouped_number~Country+grouped_answer, data=threat_numPeople)
threat.mat
```

```
##                grouped_answer
## Country          no  yes
##    Denmark       300  799
##    United.States 892 2203
```

```
chisq.test(threat.mat)
```

```
##
```

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```
##  Pearson's Chi-squared test with Yates' continuity correction
##
## data:  threat.mat
## X-squared = 0.85151, df = 1, p-value = 0.3561
```

Pretending 'Don't know' is a negative response, there is not a significant difference in how much of a threat climate change is perceived as by Danes and Americans.

```
## `summarise()` has grouped output by 'Country'. You can override using the
## `.groups` argument.
```

```
##                 grouped_answer
## Country           no  yes
##    Denmark       193  799
##    United.States 690 2203
```

```
##
##  Pearson's Chi-squared test with Yates' continuity correction
##
## data:  threat2.mat
## X-squared = 7.8763, df = 1, p-value = 0.005009
```

Removing the 'Don't know'responses yields a p value of 0.005, so I can reject the Null hypothesis. Significantly more Danes think that within the next 20 years climate change is a serious threat. See the discussion for more information.

More or less Fossil Fuels

Now that we know what Danes and Americans think about climate change and how worried they are, lets see how they are reacting. This next survey question asked people if their region should use more or less fossil fuels with the options being much more, somewhat more, same as today (same amount), somewhat less, or much less.

```
#Parcing out just the survey answers regarding climate change beliefs
fuels<- survey %>% filter(survey$question=="Ques__Fossil_moreorless")
```
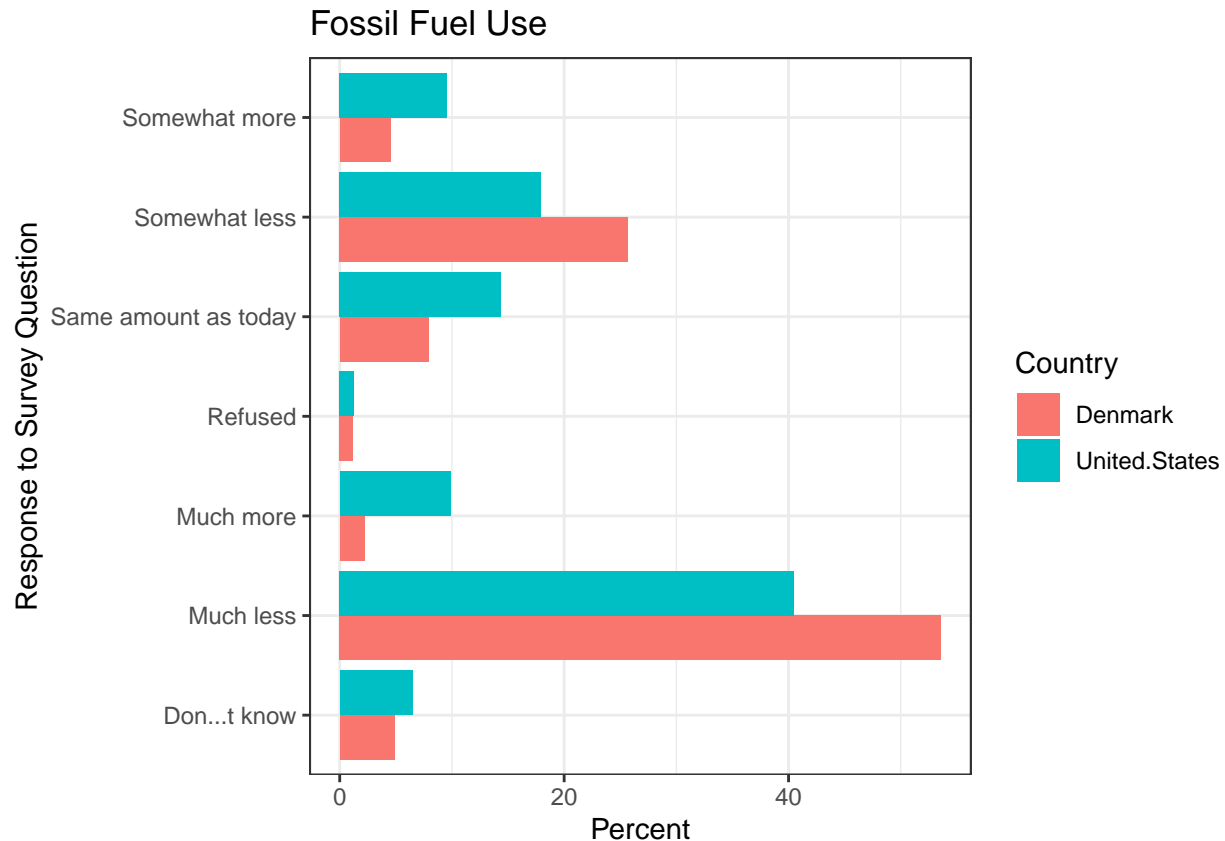
Figure 7. The fossil fuel usage Danes and Americans think their area should use. Response is in percentage of the total surveyed.

More Americans think there should be much more or or somewhat more fossil fuels used than Danes. More Danes thinks threre should be somewhat less or much less fossil fuels used. This appears to clearly show that Danes think fossil fuel usage should be decreased, where at Americans think that less. Lets see in diverging bar graph.

Given the small number of people who answered, refused, it will be left out for clairty of the diverging bar graph.

Again the option "Don't know" is present. This also has the option of same amount as today. According to the IPCC humans must decrease their emissions to stay well below 2 degrees of warming and avoid the most severe impacts of climate change, therefore, keeping it the same will go on the negative side of the diverging bar graph. Not many people chose "Don't know," plus it is difficult to predict, so I believe it is fair to leave it out.

How Much Fossil Fuels Should Your Country Use?

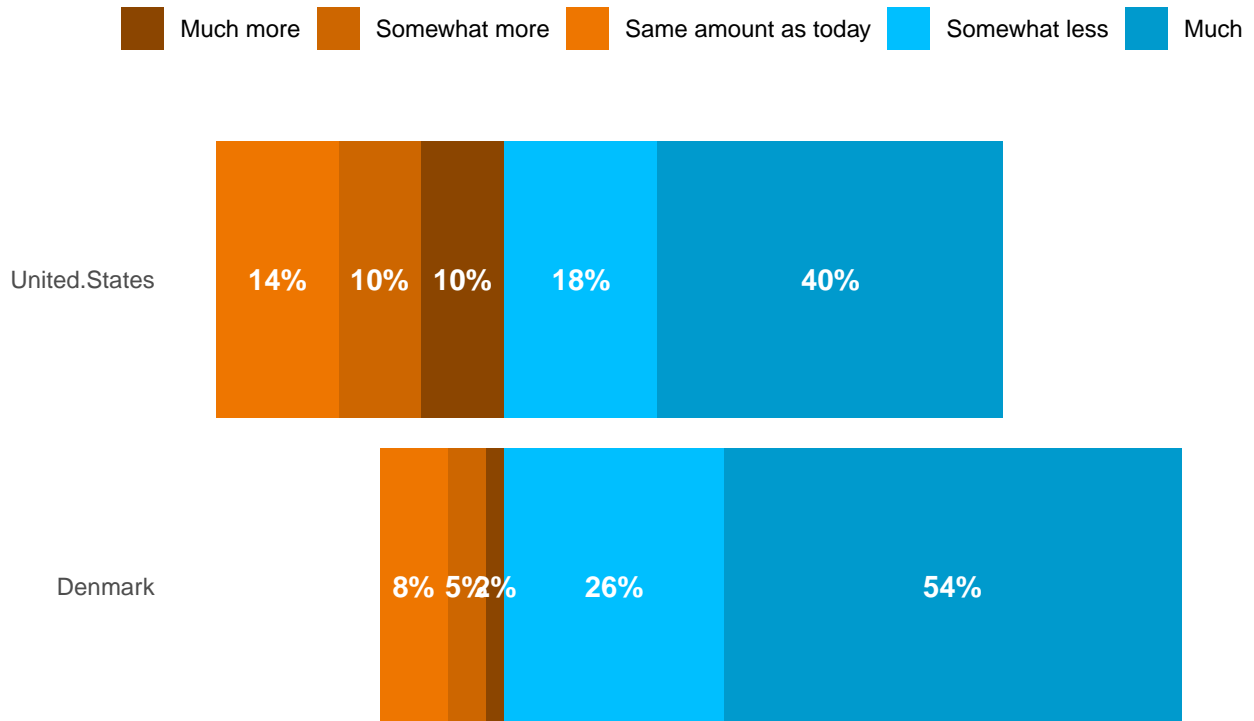Much more   Somewhat more   Same amount as today   Somewhat less   Much

Figure 8. The fossil fuel usage Danes and Americans think their area should use. Response is in percentage of the total surveyed.

The diverging bar graph shows that most of the Danes surveyed, 54%, believed much less fossil fuels should be used, with the second largest percentage of 26% believed somewhat less should be used. These percentages are larger than results in the United states, though the largest percentage of Americans also believed there should be much less fossil fuel usage at 40%, with the second most thinking somewhat less fossil fuel usage, 18%. More Americans believed there should be much more or somewhat more fossil fuel usage than Danes. There is also a visible difference in the overall diverging bar graphs, sugesting that more Danes believe their country should use less fossil fuels, than Americans believed. Lets verify with a statistical test.

we will run chi-squared test.

Running the Statistical Test

```
## `summarise()` has grouped output by 'Country'. You can override using the
## `.groups` argument.

##               grouped_answer
## Country        less more
##   Denmark       873  161
##   United.States 1808 1047

##
##  Pearson's Chi-squared test with Yates' continuity correction
##
## data:  fuels.mat
```

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```
## X-squared = 156.87, df = 1, p-value < 2.2e-16
```

The p-value is 2.2*10^-16, much less than 0.05, meaning we can reject the null hypothesis. Significantly more Danes believe their country should use less fossil fuels, than Americans.

Summary Discussion

Denmark emits significantly less per capita greenhouse emissions than the United states. My results also showed that significantly more Danes believed climate change was human caused, were more worried abut climate change, and think their country should decrease fossil fuel usage than Americans did. Overall, Danes' answers to the survey questions were significantly more planet friendly than Americans. Danish citizen's perceptions of climate change could be why Denmark emits significantly less greenhouse gas emissions per person than the United States.

It was difficult to asses the 'to what degree in the next 20 years is climate change a threat question', due to the "don't know" option. With it, there was no significant difference in responses between the countries. If I do not include it Denmark thought climate change was a bigger threat than the United States. On one hand people who answered do not know probably don't partake in climate change related activities such as voting for policies, making their decisions neutral. On the other hand, it could mean the person would lean against climate policies, not really considering climate change a pertinent issue to them personally. It is difficult to determine how someone who answered don't know would react, so not including it seems reasonable. Furthermore, given Denmark answered significantly more favorably in the three other questions, a significant p value when removing the "don't know" responses is not surprising. However, it is interesting that more Danes answered did not know to this question than Americans.

Limitations

There were not many limitaitons with the emissions data, aside from missing 2019-2023 emissions, which may have showed an interesting emissions and rate of emisisons correlation.

The data used is from the survey data was conducted on Facebook, so all respondents are Facebook users. This adds a confounding variable, when utilizing this study. However, the data was weighted to account for any biases, so the limitation does not render the data moot.

It is surprising, however, that the survey data did not have the option 'minor threat' or 'small threat' for the threat within the next 20 years question, to balance out the likert data scale in place of the don't know option. The don't know options makes it difficult to properly compare Danes and Americans opinions regarding regarding that question.

Challenges

The two data sets were both in wide format, with the survey data being particularly cumbersome, given each question was on a separate sheet. The emissions data also had x's infront of all its date entries and the dates were listed as factor data. I used sapply and lapply to fix this, which I had to research and teach myself. Overall however, the exploratory anayslis was not as challenging as the next step.

Prior to this project how to conduct a two paired t-test, work with survey data, or make diverging bar graphs was not discussed nor taught. External research and problem solving had to be conducted in order to achieve this for the final analysis.

When constructing graphs the diverging bar graphs proved to be particularly cumbersome as the labels, bars, and bar colors all needed to be in the same appropiate order. The first beliefs survey data was difficult for this, because the answers to the survey were so long, they could not all fit on the bar graph. Given diverging

bar graphs are parced out based on the available factor levels of the data I could not change the long data responses, so instead I provided an image people can view along with the pdf to see the graph better.