

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 analyze 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 1950-2021 whereas Denmark has one of the most ambitious emission reduction plans in the world.⁴ The emissions 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>.

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

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

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

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

⁵Gunster, 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

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

Statistical 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

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

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.

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

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

```
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
# 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.

```
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
```

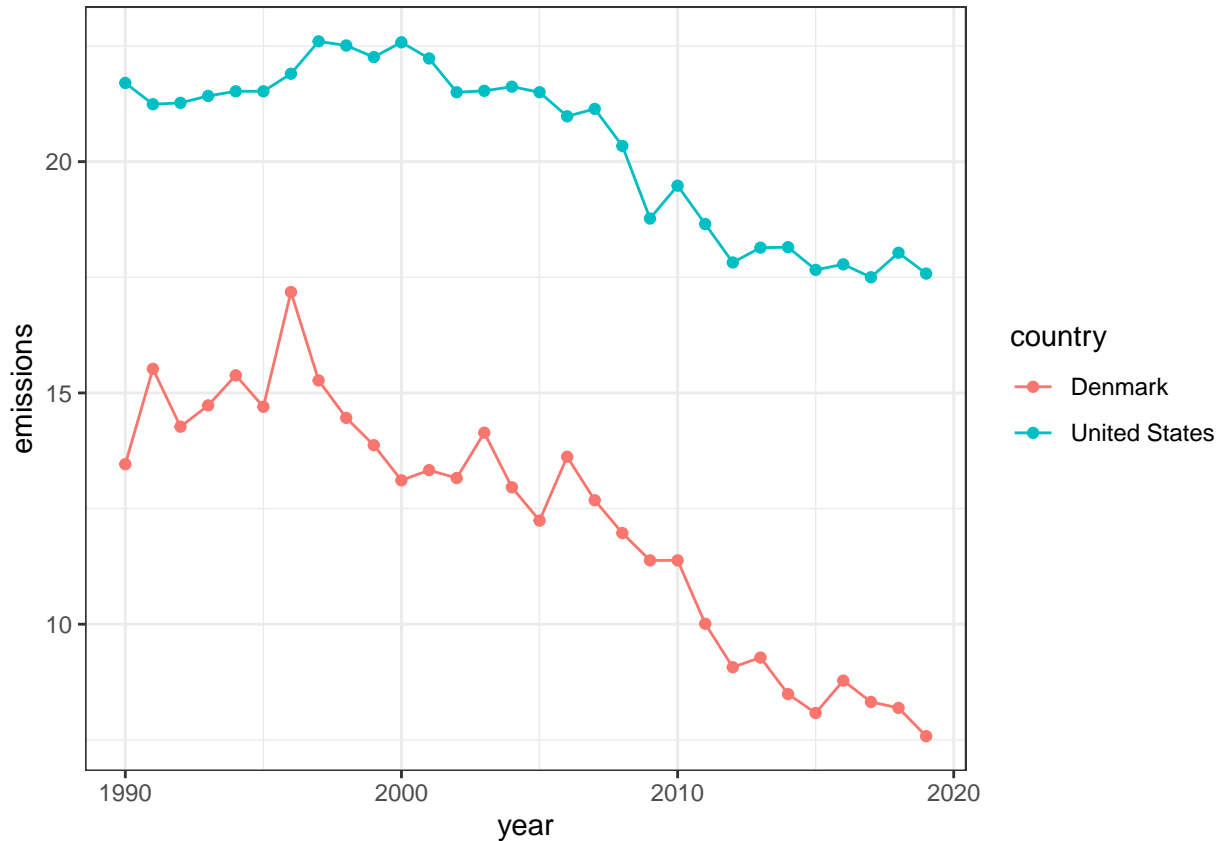


Figure 1. Per capita greenhouse gas emissions of Denmark and the U.S. from 1990 to 2019.

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)

##
## 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
#like running a t test, but tell r the data is paired.
```

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, and group tells R to group the
```

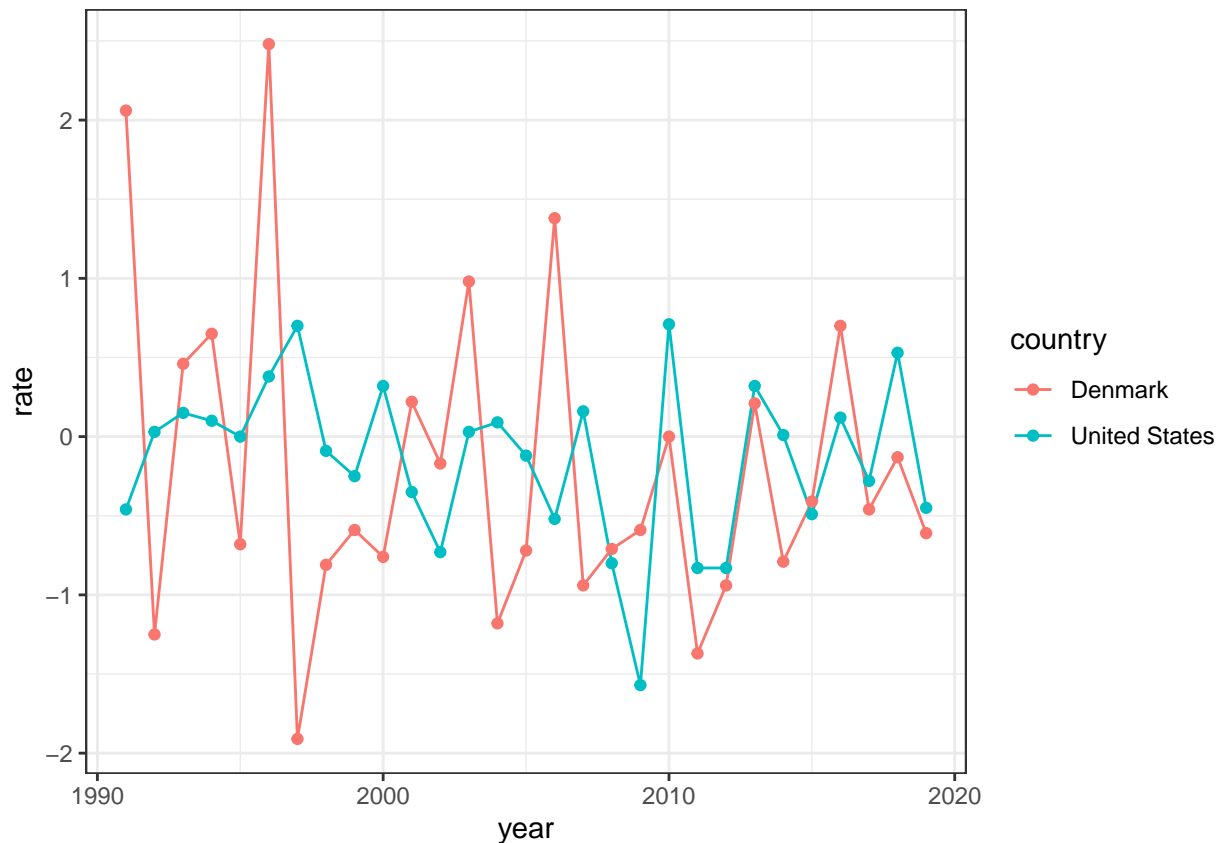
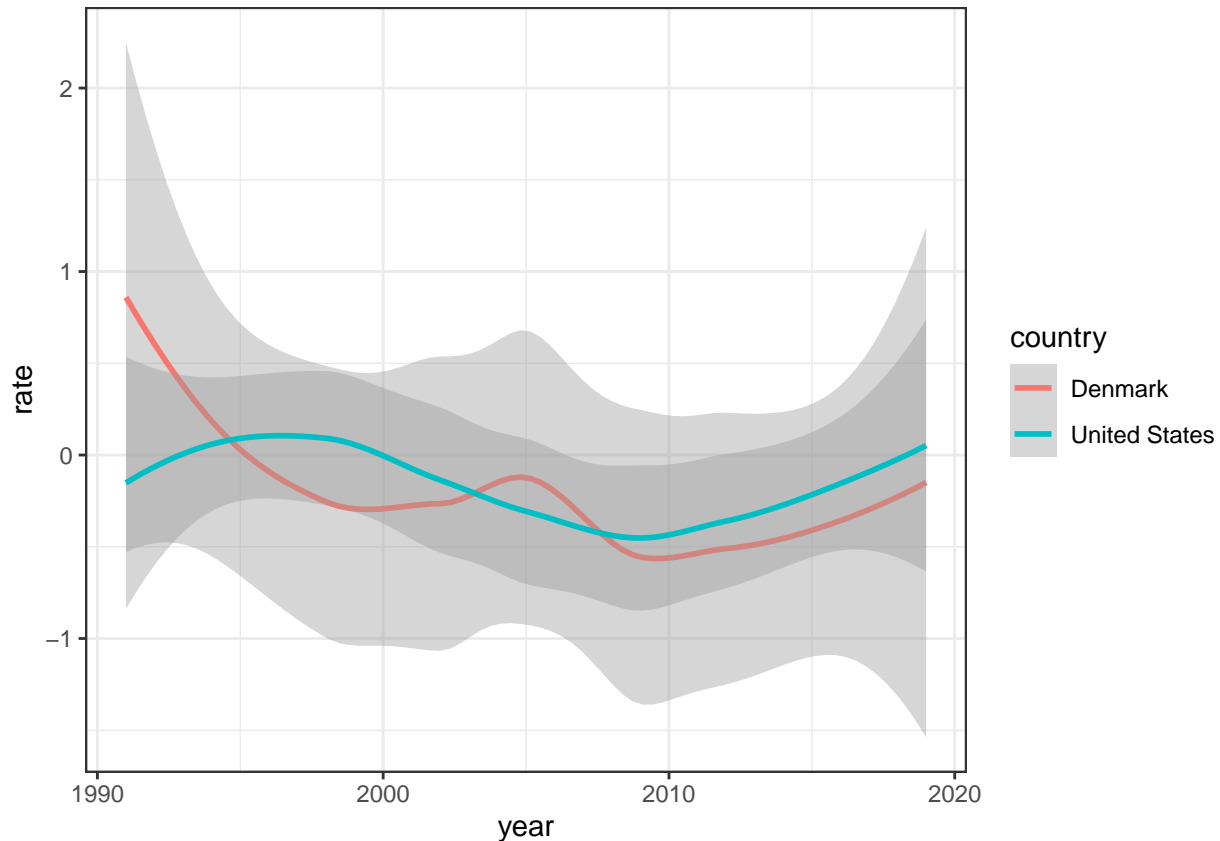


Figure 2. The rate of per capita greenhouse gas emissions for Denmark and the U.S. from 1990 to 2019.

There is a lot of added noise, making it difficult to see overall trends. Let's view the rate data smoothed over.

```
ggplot(emissions_rate, aes(year, rate, colour= country, group=country)) +
  geom_smooth() + theme_bw() #colour colors by country, and group tells R to
```

```
## `geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```



```
#group the points by country so geom_line will draw lines connecting the  
#data by country.
```

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.

```
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
```

#complete.cases means just use the ones without NAs

Looking at the entire range from 1990-2019, the p value is 0.7668, so we must accept the Null hypothesis. 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 significant. 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=FALSE)
```

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")
```

```
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 re
  #theme( axis.text.x = element_text(angle = 45, size = 13, vjust = 0.5))+ this won't work :(
  coord_flip()+
  theme_bw()
```

```
## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'None of the above because climate change isn't happening'
## in 'mbscsToSbcs': dot substituted for <e2>

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'None of the above because climate change isn't happening'
## in 'mbscsToSbcs': dot substituted for <80>

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
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## in 'mbscsToSbcs': dot substituted for <e2>

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
```



```

## in 'mbcsToSbcs': dot substituted for <80>

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```

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## conversion failure on 'None of the above because climate change isn't happening'
## in 'mbcsToSbcs': dot substituted for <99>

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## conversion failure on 'None of the above because climate change isn't happening'
## in 'mbcsToSbcs': dot substituted for <e2>

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'None of the above because climate change isn't happening'
## in 'mbcsToSbcs': dot substituted for <80>

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'None of the above because climate change isn't happening'
## in 'mbcsToSbcs': dot substituted for <99>

## Warning in grid.Call.graphics(C_text, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'None of the above because climate change isn't happening'
## in 'mbcsToSbcs': dot substituted for <e2>

## Warning in grid.Call.graphics(C_text, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'None of the above because climate change isn't happening'
## in 'mbcsToSbcs': dot substituted for <80>

## Warning in grid.Call.graphics(C_text, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'None of the above because climate change isn't happening'
## in 'mbcsToSbcs': dot substituted for <99>
```

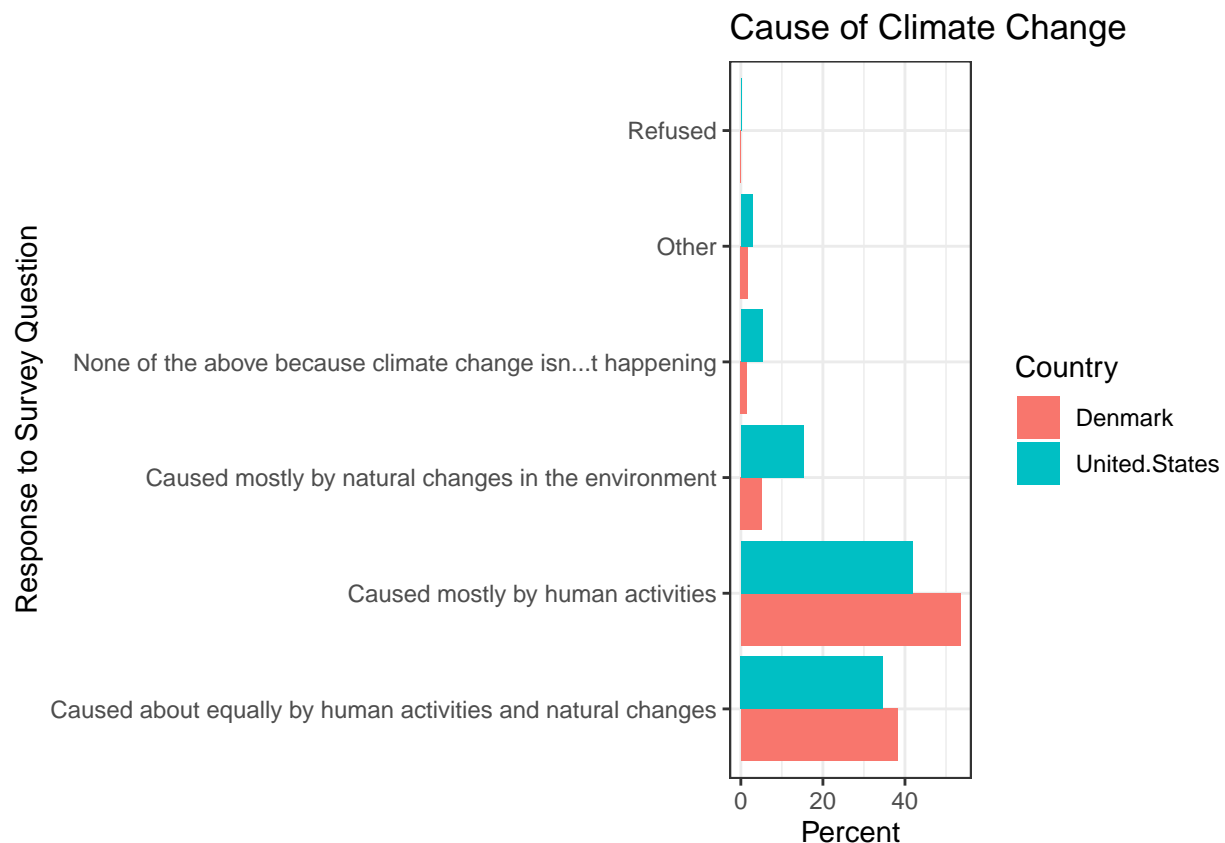


Figure 4. What Danes and Americans believe caused climate change. Responses are in percent of the total surveyed.

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 caused equally by both.

To get a better sense of the of which country answers were more beneficial for combating climate change, let's look at a diverging bar graph. In this graph 'good' answers, in this case that climate change is caused by human activity, is made positive and 'bad' answers, 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(
#all the percentages in the response column that did not answer "caused mostly by human activities" w

#first line below takes the Number column rounds it up, takes the absolute value of it and adds a % for
beliefs_diverging<- beliefs_diverging %>% mutate(percent=paste0(round( abs(Number), digits=1), "%"))

ggplot(beliefs_diverging, 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")+
  coord_flip()+
  scale_x_discrete()+
  scale_fill_viridis_d()+
  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")
```

```
## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'None of the above because climate change isn't happening'
## in 'mbsToSbcs': dot substituted for <e2>

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'None of the above because climate change isn't happening'
## in 'mbsToSbcs': dot substituted for <80>

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'None of the above because climate change isn't happening'
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```

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## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :

```



```

## in 'mbcsToSbcs': dot substituted for <99>

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## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
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```

```
## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :  
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## in 'mbcsToSbcs': dot substituted for <e2>  
  
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```

```
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## conversion failure on 'None of the above because climate change isn't happening'
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## conversion failure on 'None of the above because climate change isn't happening'
## in 'mbcsToSbcs': dot substituted for <80>

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## conversion failure on 'None of the above because climate change isn't happening'
## in 'mbcsToSbcs': dot substituted for <99>
```

What do you Think Caused Climate Change

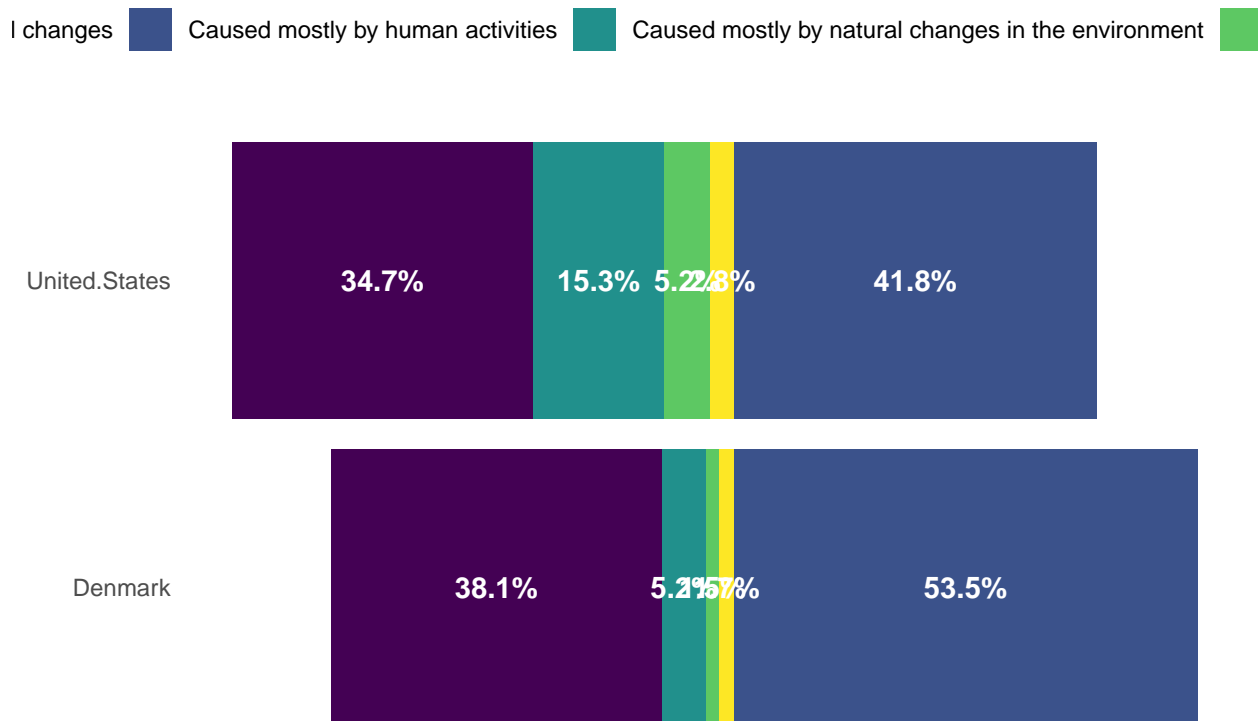


Figure 4. Diverging Bar graph what Danes and Americans believe caused climate change. Responses are in percent of the total surveyed.

Here's an article that talks more about data viz for likert type data. It has good arguments for why to avoid pie charts, and has a building series of charts ending with the author's (and my) favorite. Just worth considering:

<https://nightingaledvs.com/visualizing-likert-scale-data-same-data-displayed-seven-different-ways/>

The pie chart 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.

We have multiple categorical predictor variables with the response variable being ratio data that bounded between 0 and 100%, so we will run a _____

Chi-square test after converting percents to numbers by multiplying the percents times the total number of respondents to that question per country.

INSERT ### Running the Statistical Test

Level of worriedness about Climate Changed In this survey question people were asked how worried they are about climate change. There are three options for

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

```
ggplot(worry, aes(response,Number, fill=Country))+geom_bar(stat = 'identity') +  
  labs(title="Level of Concern Over Climate Change", x="Response to Survey Question", y="Percent") + th
```

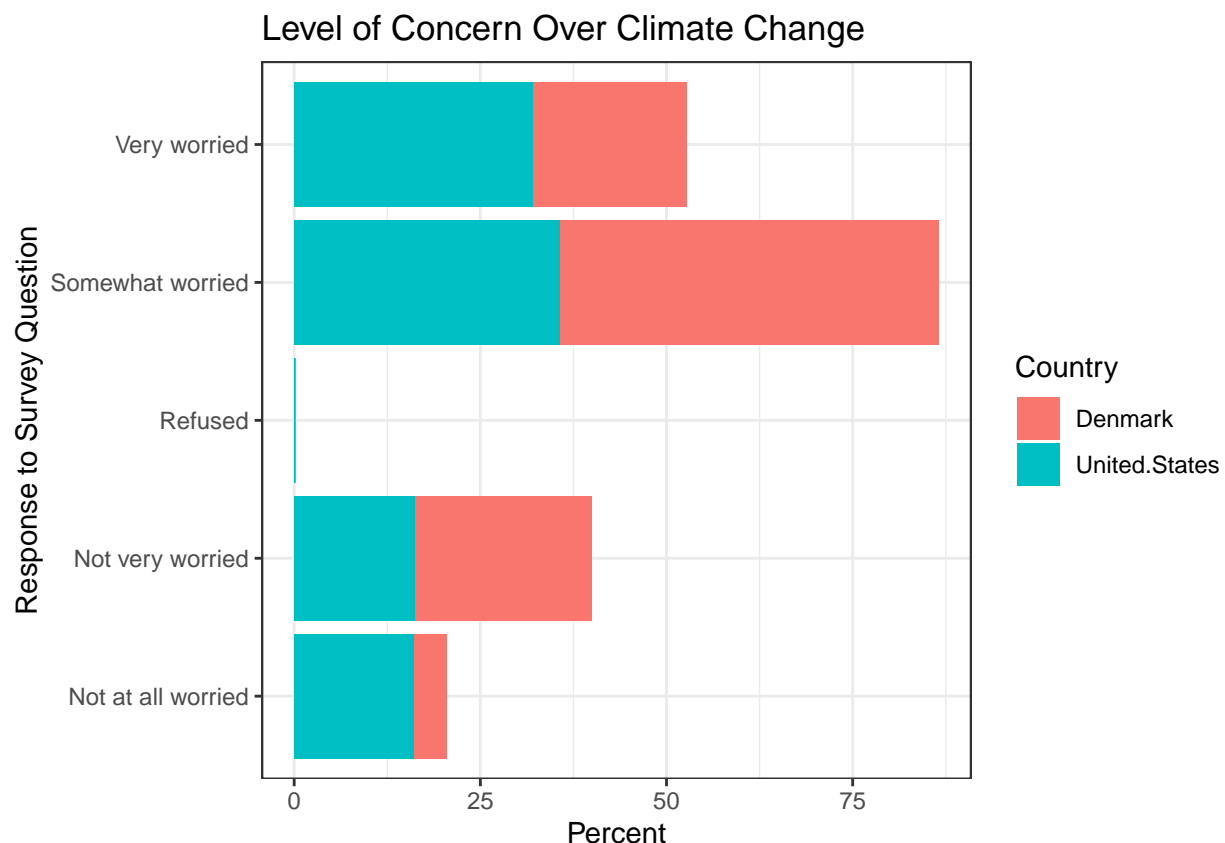


Figure 3. Bar graph of the Level of Concern over climate change of both Danes and Americans. Response is in percentage of the total surveyed.

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 try another graph.

```
ggplot(worry, aes(x="", y= Number, fill=response))+ geom_bar(stat="identity", width=1)+ coord_polar("y")
  geom_label(aes(label = round(Number, digits = 1)), nudge_x = 0.4) + # add percentages
  theme_void()+ # remove background, grid, numeric labels
  facet_wrap(~Country)
```

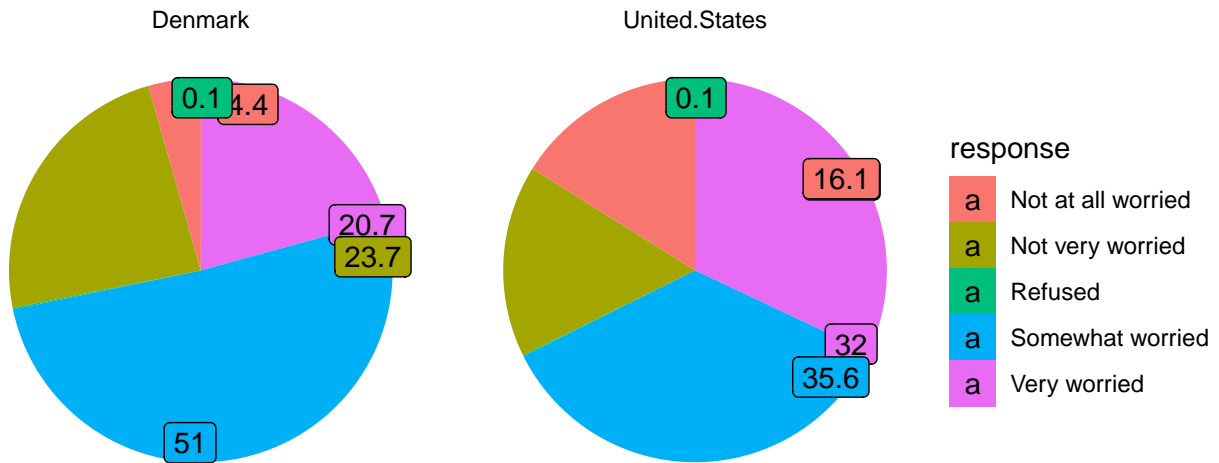


Figure 4. Pie chart of the Level of Concern over climate change of both Danes and Americans. Response is in percentage of the total surveyed.

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 too Denmark (51% to 35.6%). More Americans however are very worried, and more Americans are not at all worried than Danes. Interesting. A statistical test is needed to see if Americans are less worried than Danes.

Lets do a statistical test to verify. Chi-square test. And think about a new data vis.

INSERT STATISTICAL TEST

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")
```

```
ggplot(threat, aes(response, Number, fill=Country))+geom_bar(stat = 'identity', position = 'dodge') +
  labs(title="Perceieved Threat of Climate Change", x="Response to Survey Question", y="Percent") + the
```

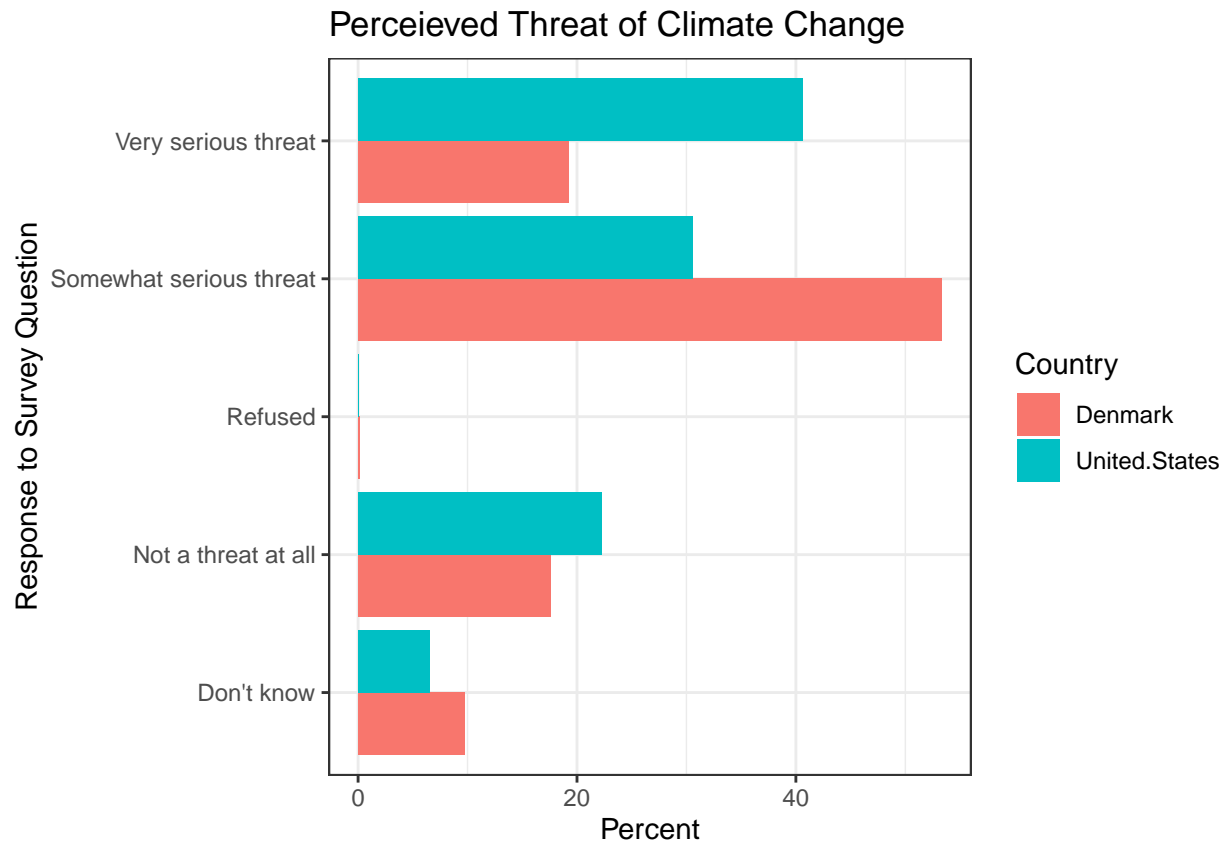


Figure 5. Bar graph of the perceieved threat of climate change of Danes and Americans. Response is in percentage of the total surveyed.

More Americans than Danes think that climate change is a very serious threat, but 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 pie chart.

```
ggplot(threat, aes(x="", y= Number, fill=response))+ geom_bar(stat="identity", width=1)+ coord_polar("r")
  geom_label(aes(label = round(Number, digits = 1)), nudge_x = 0.5, nudge_y = 2 ) + # add percentages
  theme_void()+ # remove background, grid, numeric labels
  facet_wrap(~Country)
```

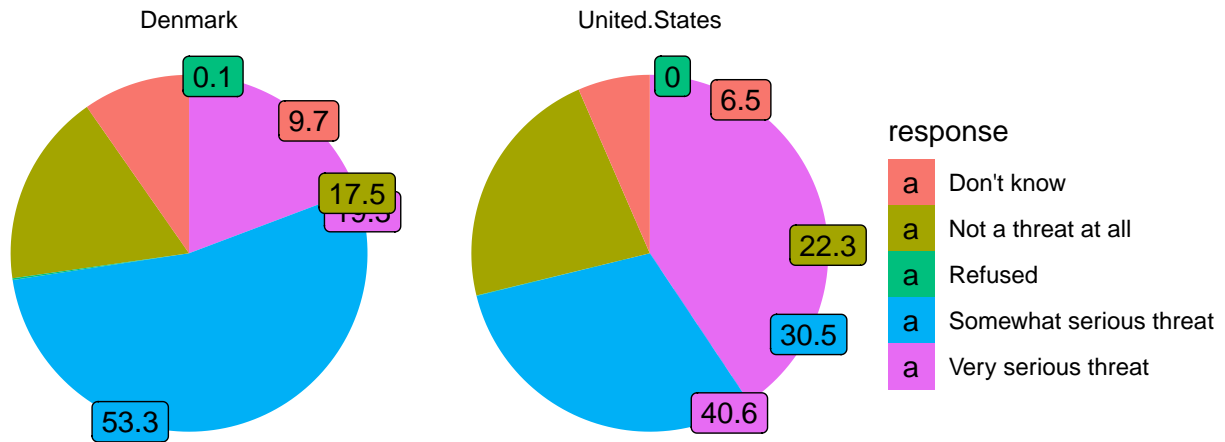


Figure 6. Pie char of the perceieved threat of climate change of Danes and Americans. Response is in percentage of the total surveyed.

We can see that most Danes, %53 think climate change is a somewhat serious threat, whereas 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. Lets test with a statistical test.

Lets do a statistical test to verify. *###INSERT STATISTICAL TEST*

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.

Lets check with the 'beilefs question' which is the first we will anaylzed.

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

```
# Making the graph
```

```
ggplot(fuels, aes(response,Number, fill=Country))+geom_bar(stat = 'identity', position = 'dodge') +
  labs(title="Fossil Fuel Use", x="Response to Survey Question", y="Percent") + # renaming x and y axis
  theme_bw() +
  coord_flip() # switching x and y axis to read the suvey questions
```

[illegible]

[illegible]

```
## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'Don't know' in 'mbcsToSbcs': dot substituted for <e2>

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
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```

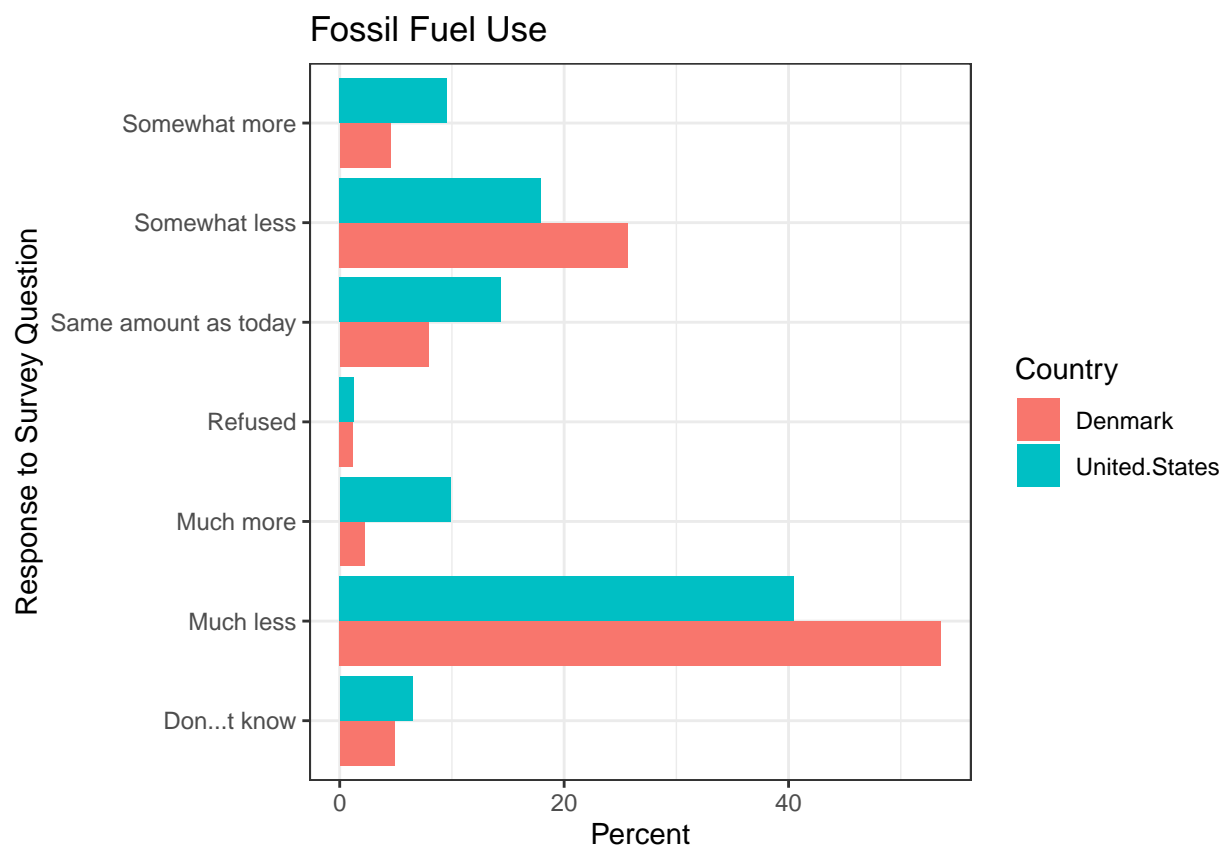


Figure 7. The fossil fuel usage Danes and Americans think their area should use. Response is in percentage of the total surveyed.

More Americans think there should be much more or or somewhat more fossil fuels used than Danes. More Danes thinks there 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 Americans think that less. Let's see in pie chart form.

```
ggplot(fuels, aes(x="", y= Number, fill=response))+ geom_bar(stat="identity", width=1)+ coord_polar("y")
  geom_label(aes(label = round(Number, digits = 1)), nudge_x = 0.4) + # add percentages
  theme_void()+ # remove background, grid, numeric labels
  facet_wrap(~Country)
```

[illegible]

[illegible]

[illegible]

```

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
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```

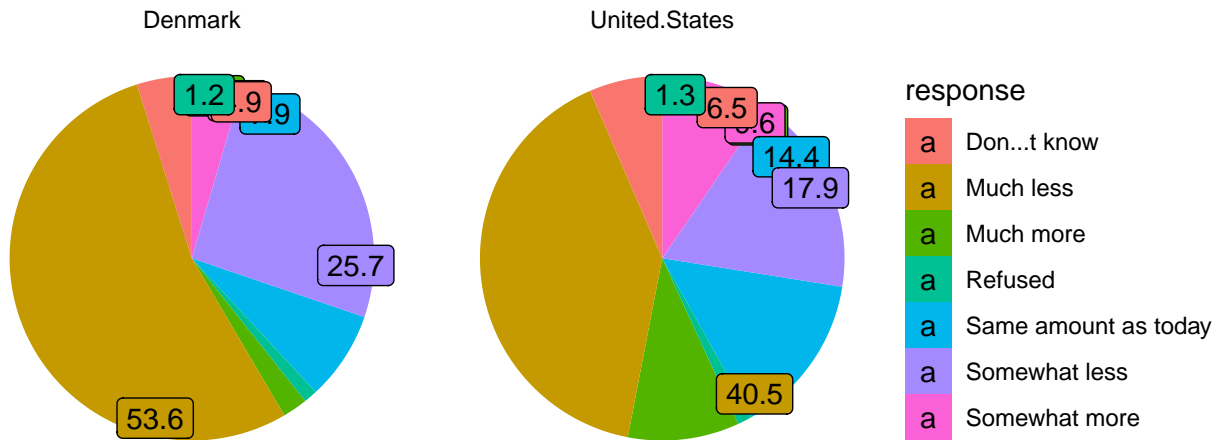


Figure 8. The fossil fuel usage Danes and Americans think their area should use. Response is in percentage of the total surveyed.

The pie chart shows that most of the Danes surveyed, %53.6, believed much less fossil fuels should be used, with the second largest percentage of 25.7% 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 40.5%, with the second most thinking somewhat less fossil fuel usage, 17.9%. More Americans believed there should be much more or somewhat more than Danes. Lets verify with a statistical test.

we will run another generalized linear model.

Running the Statistical Test ### *INSERT STATISTICAL TEST*

Survey data Impacting Emissions

Summary Discussion

Limitations

The data used is from a survey conducted on Facebook, so all respondents are Facebook users. This adds a confounding variable, when utilizing this study.

Challenges

Prior to this project how to conduct a time series analysis, work with survey data, or make pie charts was not discussed nor taught. External research and problem solving had to be conducted in order to achieve this data analysis.

What about challenges in terms of figuring out how to reshape/reformat your data? Anything worth mentioning there?

This is very thorough and a solid first draft.

When constructing graphs the pie charts proved to be particularly cumbersome as the percentages were not align on the pie chart in the correct spot, nor all be visible. Research into `geom_label` and `geom_text` yielded a the most succesful outcome. However, the pie charts still need work and any feedback regarding how to would be greatly appreciated.

Research into how to make a likert graph was also conducted. The responses to the four survey questions would have to be the same however, in order to produce a likert graph. I could change the answers to create a made up response scale of pro or anti climate action. Would that be professional or no? Let me know your thoughts so I can include it in the final.