Sankey Diagrams and Network Analysis

Special thanks to Dr. Scerri and Dr. Lucero

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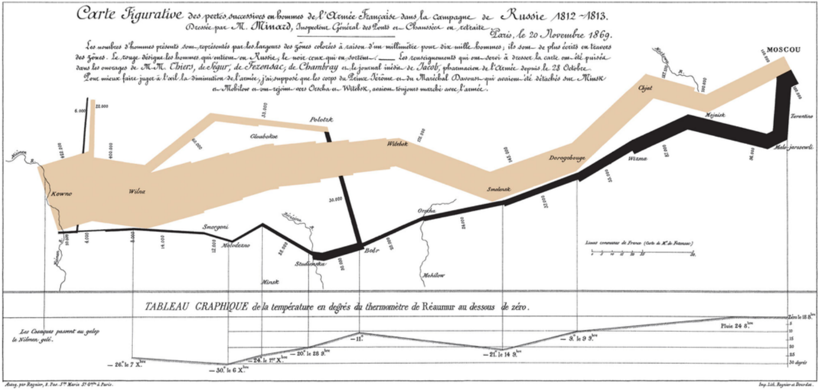
Introduction

- What is a Sankey Diagram?
  - Simply put, method to visualize data that "flows" between different processes
  - Example use cases: linking majors to careers, energy consumption, life-time of bills
- Sankey diagrams are named after a man named Matthew Henry Sankey who used it to demonstrate the efficiency of energy transfer within a steam engine

Examples


Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.
Dressée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite.
Paris, le 20 Novembre 1869.
Les nombres d'hommes présents sont représentés par les largeurs des zônes colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en travers des zônes. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. —— Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M.M. Thiers, de Ségur, de Fezensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre.
Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davoust qui avaient été détachés sur Minsk et Mobilow et ont rejoint vers Orscha et Witebsk, avaient toujours marché avec l'armée.
MOSCOU
Kowno
Wilna
Smorgoni
Molodezno
Glouboko
Polotzk
Witebsk
Smolensk
Dorogobouge
Wizma
Chjat
Mojaisk
Tarantino
Malo-jarosewli
Orscha
Bobr
Studienska
Minsk
Mohilow
TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.
Les Cosaques passent au galop le Niémen gelé.
— 26° le 7 X.bre
— 30° le 6 X.bre
— 24° le 1.er X.bre
— 20° le 28 9.bre
— 11°
— 21° le 14 9.bre
— 9° le 9 9.bre
Pluie 24 8.bre
Zéro le 18 8.bre

Another Example

image source: Ben Schmidt

Example I found here

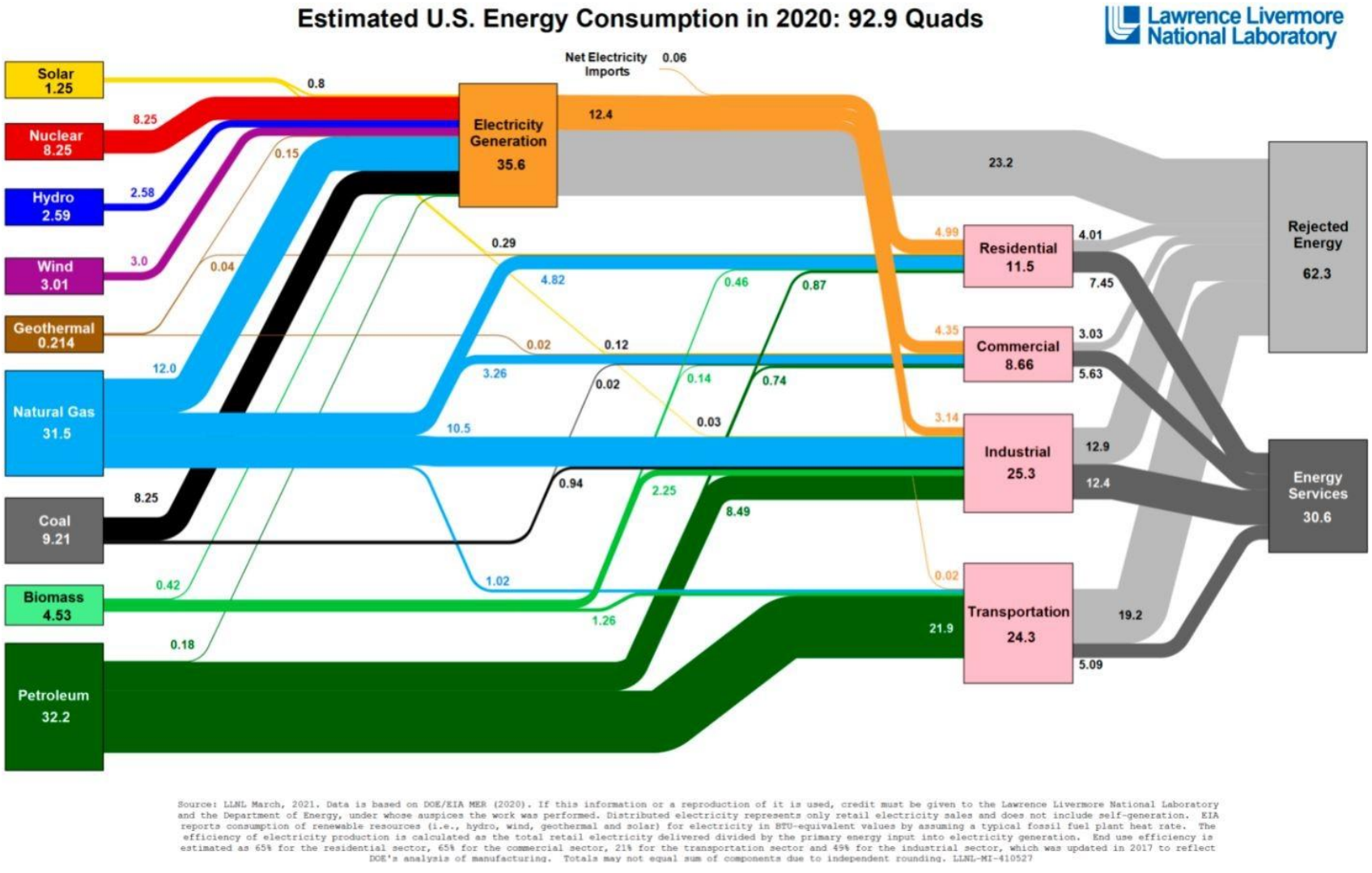


image source: Life in the Built Environment

Creating Sankeys

There are several packages that implement sankey diagrams/have sankey capabilities built on top of them. Let us start off with ggplot's implementation: ggsankey.

```
#install.packages("devtools")
#devtools::install_github("davidsjoberg/ggsankey")
library(ggsankey)
library(ggplot2)
library(dplyr)
head(mtcars[,c("gear", "cyl", "am", "carb")])
```

```
##                   gear cyl am carb
## Mazda RX4            4   6  1    4
## Mazda RX4 Wag        4   6  1    4
## Datsun 710           4   4  1    1
## Hornet 4 Drive       3   6  0    1
## Hornet Sportabout    3   8  0    2
## Valiant              3   6  0    1
```

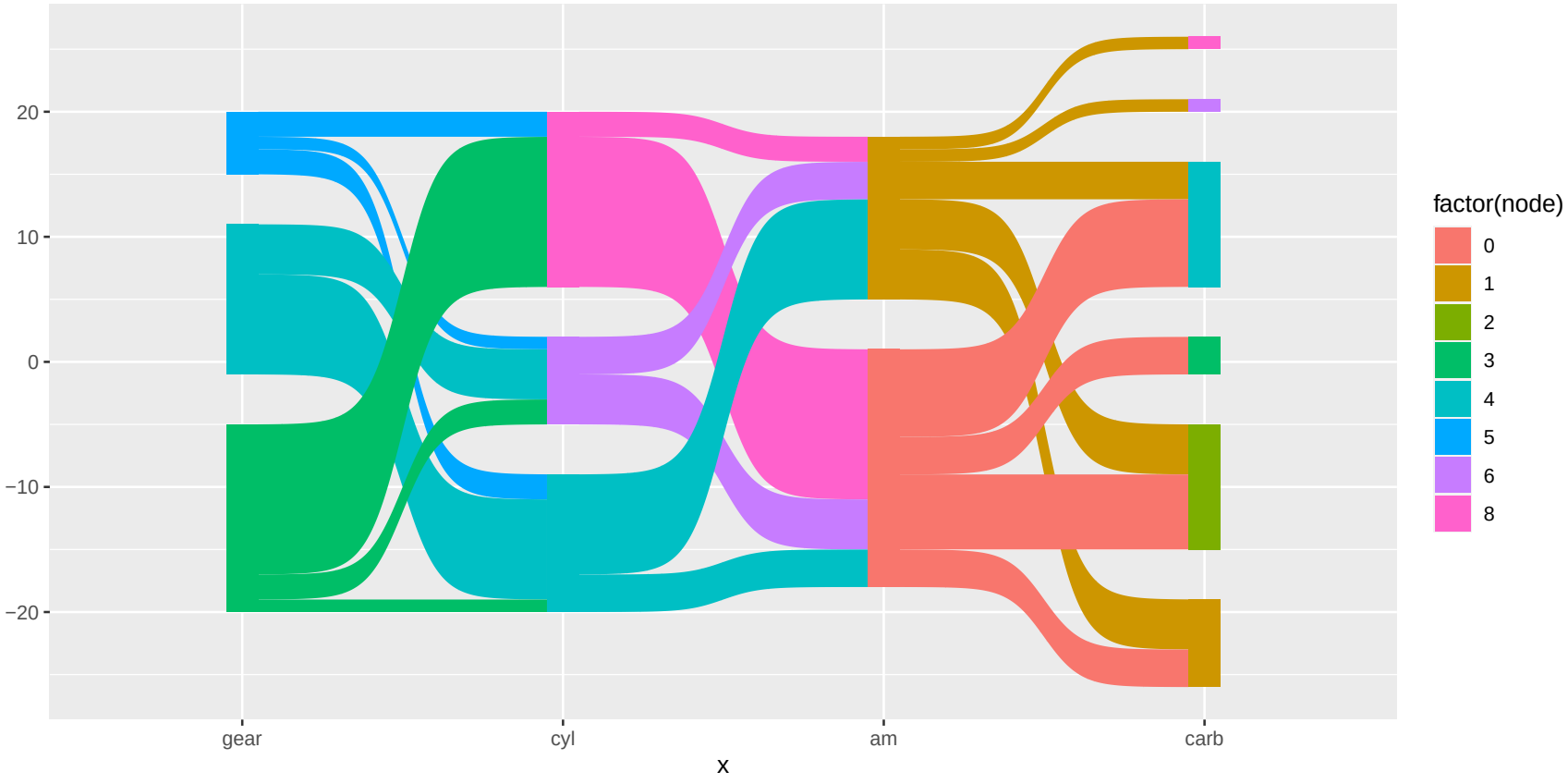
Baby Example

```
mt_sankey <- make_long(
    mtcars,
    gear,
    cyl,
    am,
    carb
)
head(mt_sankey)
```

```
## # A tibble: 6 x 4
##   x       node next_x next_node
##   <fct> <dbl> <fct>       <dbl>
## 1 gear      4 cyl             6
## 2 cyl       6 am              1
## 3 am        1 carb            4
## 4 carb      4 <NA>           NA
## 5 gear      4 cyl             6
## 6 cyl       6 am              1
```

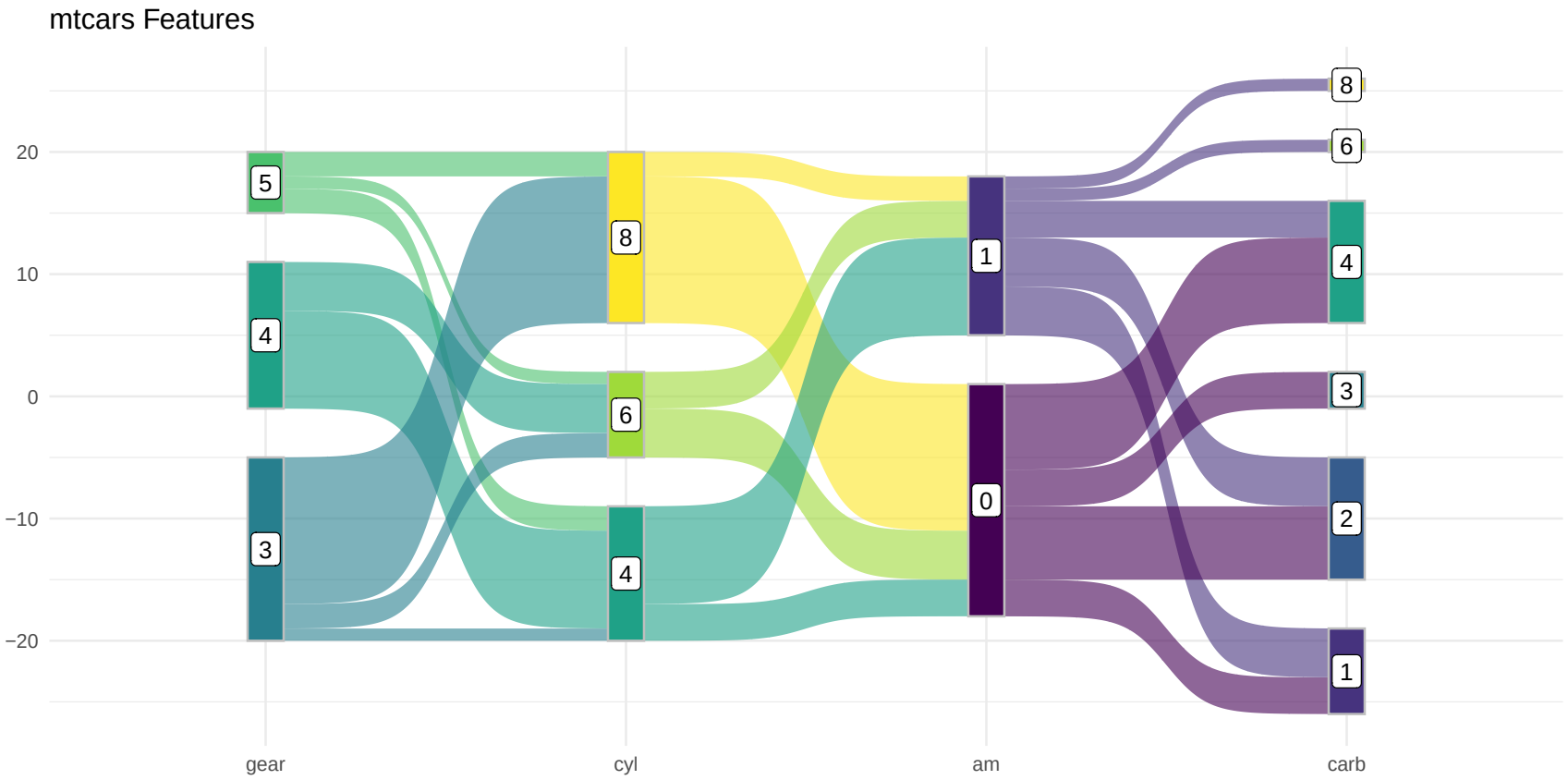
Plot

```
ggplot(mt_sankey, aes(x = x,
                      node = node,
                      next_node = next_node,
                      next_x = next_x,
                      fill = factor(node))) +
    geom_sankey()
```



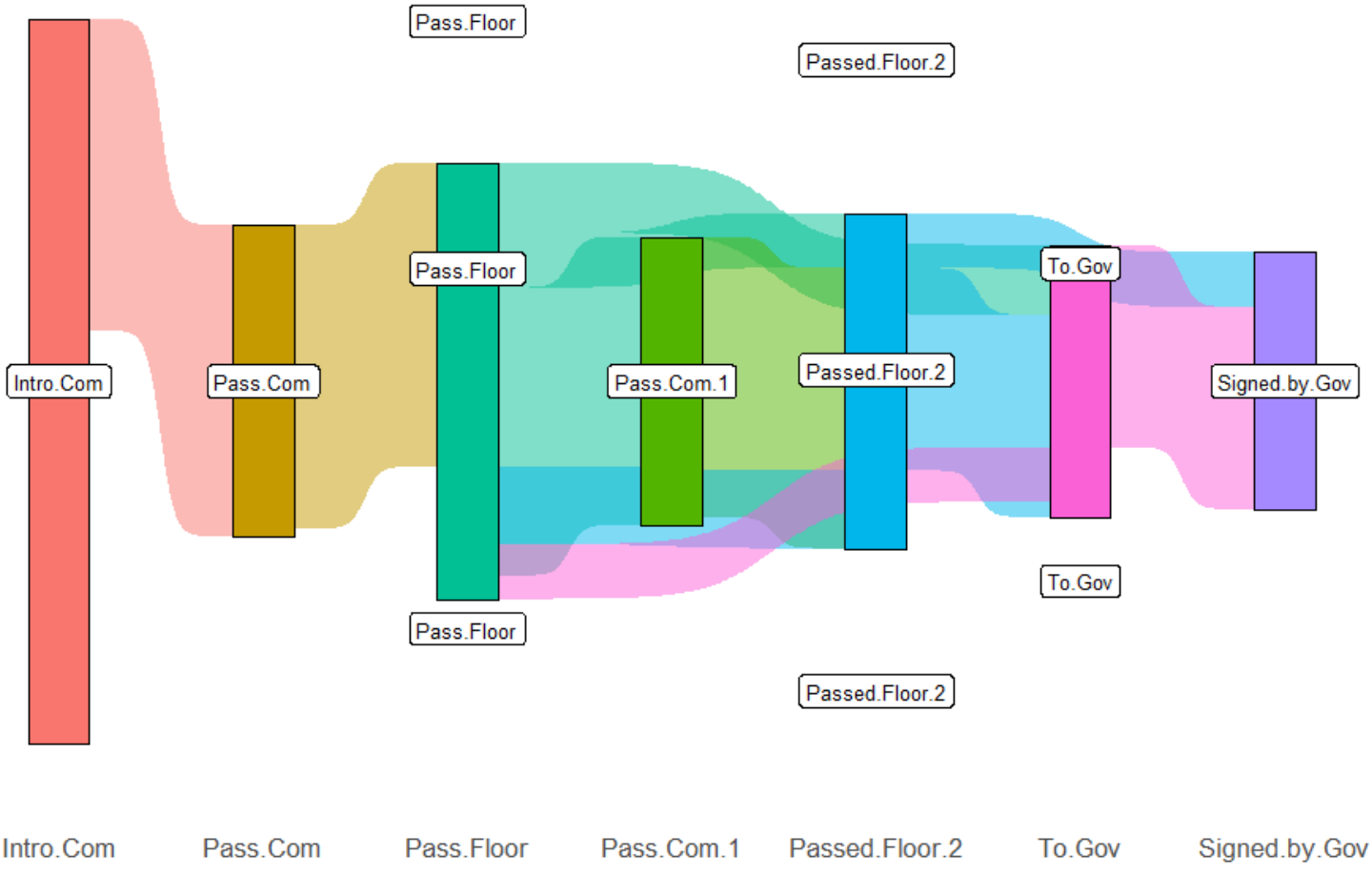
Fancier Plot

```
ggplot(mt_sankey, aes(x = x, node = node, next_node = next_node,
                      next_x = next_x, fill = factor(node))) +
    geom_sankey(flow.alpha = 0.6, node.color = "gray") +
    scale_fill_viridis_d() +
    geom_sankey_label(aes(label = node), fill = "white") +
    labs(x = NULL, title = "mtcars Features") +
    theme_minimal() + theme(legend.position = "none")
```



Some issues. . .

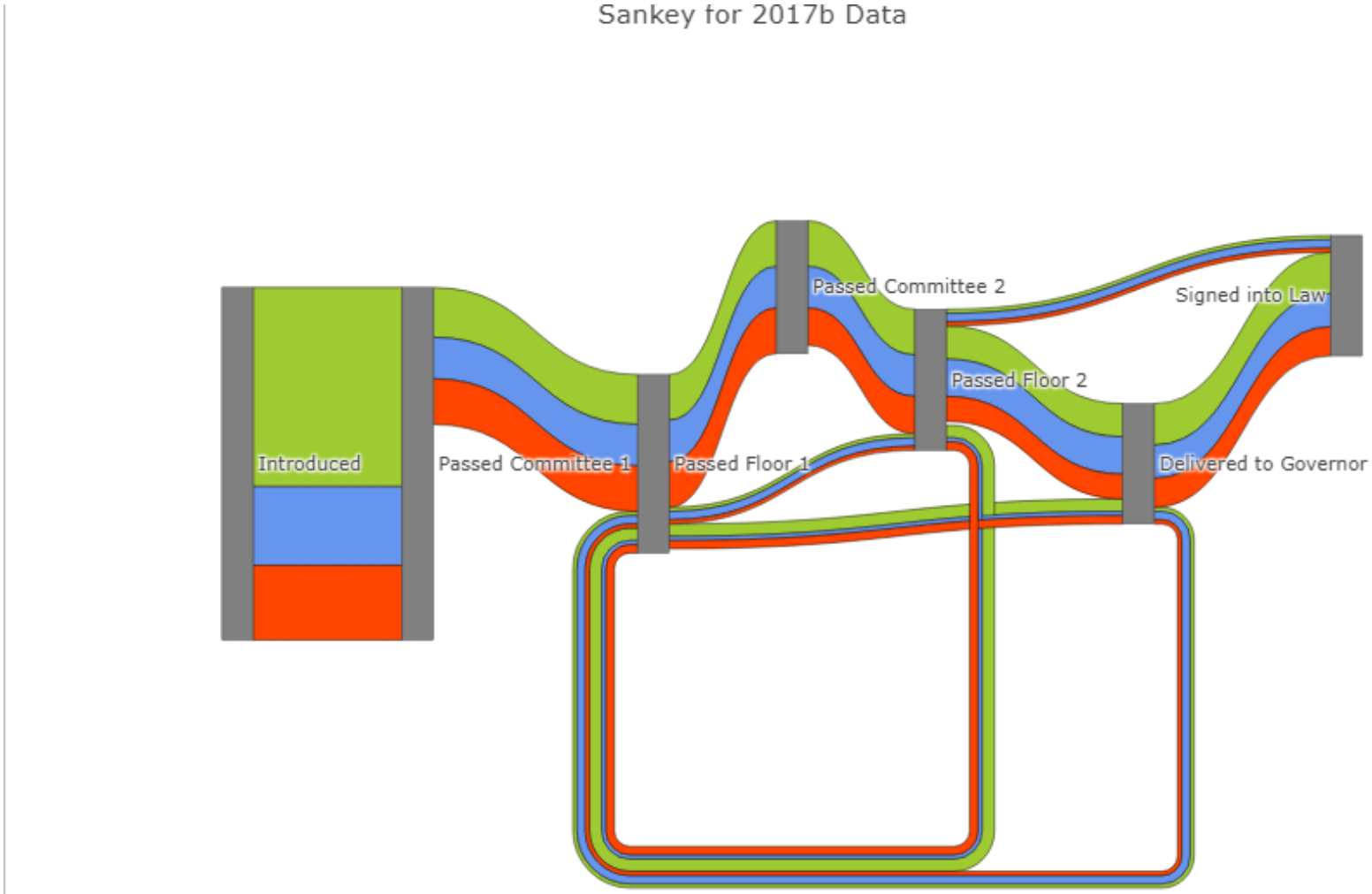
1. ggplot creates static images
2. Some. . . interesting results were generated



A New Challenger Approaches

```
#install.packages("plotly")
library(plotly)
```

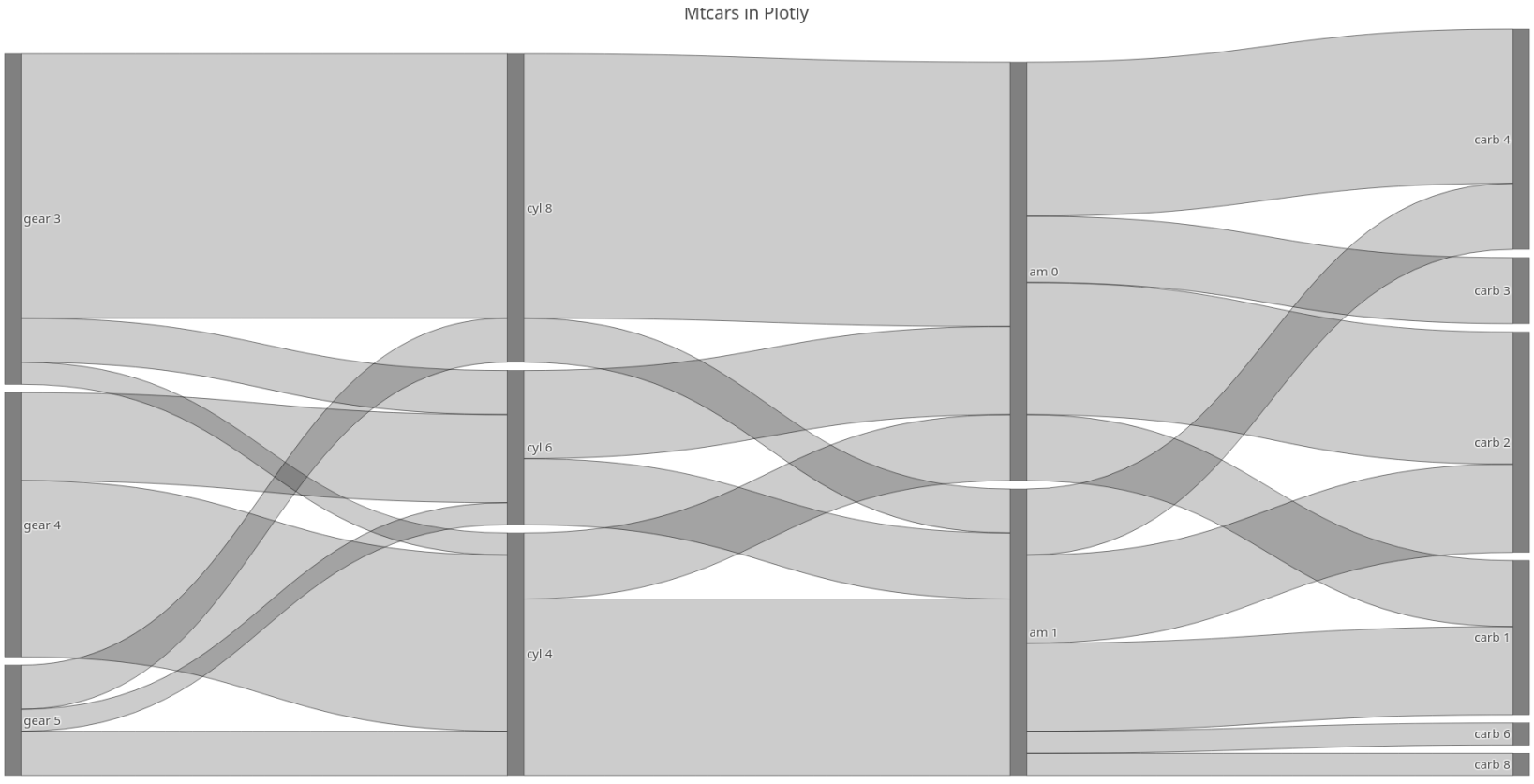
Plotly is a javascript based plotting software that can create several types of graphs, including Sankeys. It solves both of the issues mentioned above, making it the ideal choice for my research project.



Comparison in Input

```
mt_plotly <- mutate(mt_sankey, xnode = factor(paste(x, node))) %>%
    mutate(xnextnode = factor(paste(next_x, next_node),
                              levels = levels(xnode)))
levs <- (levels(mt_plotly$xnode))
mt_plotly <- filter(mt_plotly, !is.na(node), !is.na(next_x),
                    !is.na(next_node)) %>%
    group_by(xnode, xnextnode) %>% summarize(n = n())
plot_ly(
  type = "sankey", arrangement = "snap",
  node = list(color = "gray", label = levs, pad = 10),
  link = list(
    source = as.numeric(mt_plotly$xnode) - 1,
    target = as.numeric(mt_plotly$xnextnode) - 1,
    value = mt_plotly$n, line = list(color = "black", width = 0.5)
    )) %>%
  layout(title = "Mtcars in Plotly",
         xaxis = list(showgrid = F, zeroline = F),
         yaxis = list(showgrid = F, zeroline = F),
         font = list(size = 15),
         showlegend = T)
```

Output

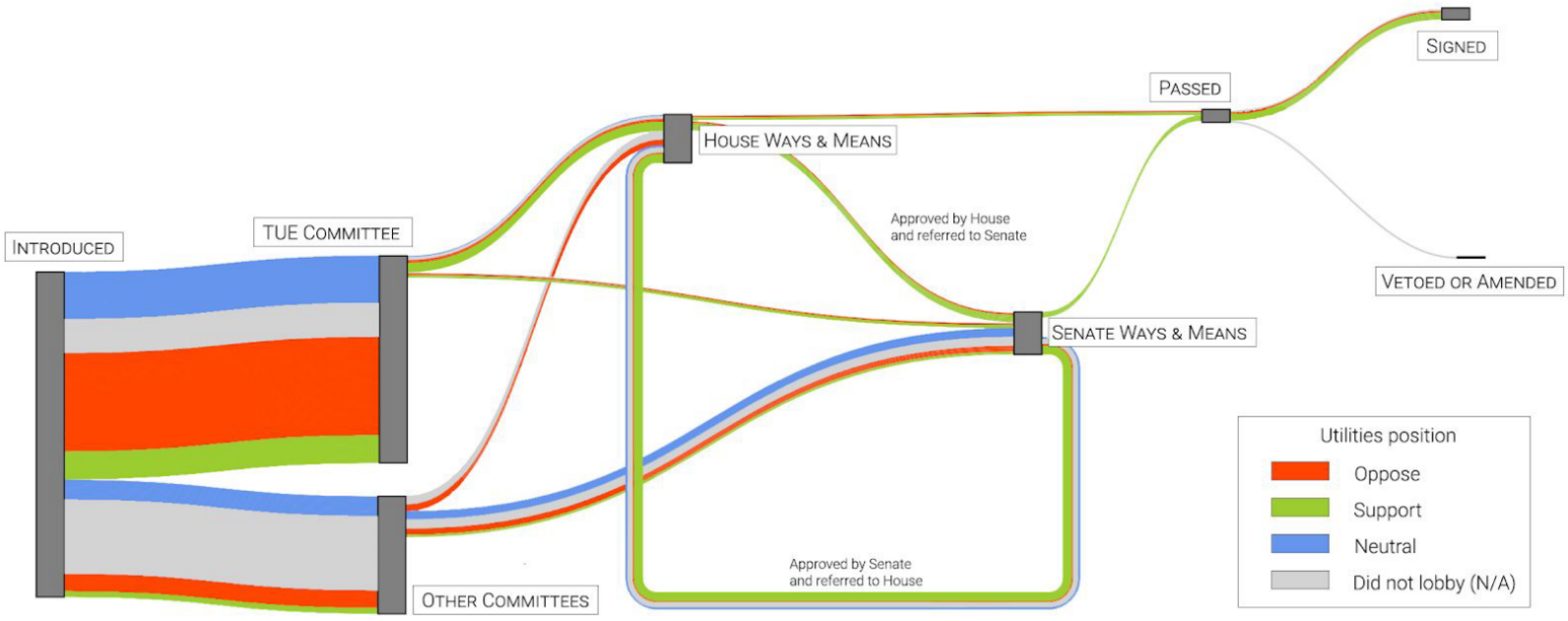

Mtcars in Plotly
gear 3
gear 4
gear 5
cyl 8
cyl 6
cyl 4
am 0
am 1
carb 4
carb 3
carb 2
carb 1
carb 6
carb 8

Research

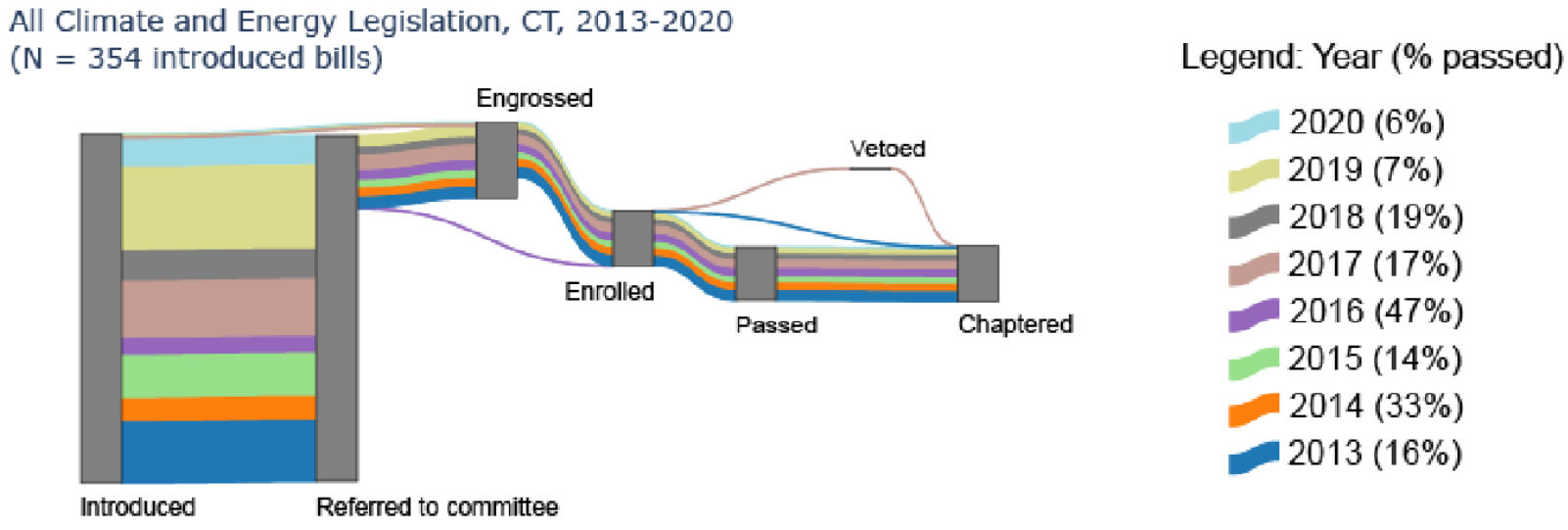
I have been working with Dr. Scerri from PSCI and the Climate Social Science Network since last semester to develop reports on the effects of lobbying on climate legislation. My role was to develop visualizations akin to what previous studies of the sort have been using.

We invited Dr. Lucero to join in for Spring semester as a research project + credit. With his guidance we developed a dashboard to allow people to look at the data for themselves.

Snippets from Massachusetts Branch of Project



Connecticut Project



Issues with Virginia

1. Lobbyists do not have to disclose the position they are lobbying for
   - Ended up collaborating with Sierra Club to approximate climate friendliness of bills
2. There is no database to easily access climate data
   - Issue with most states

Final Product (on Daniel's End of Things)

Now for a demonstration

Research Rundown

Goals

- Study relationships in climate and energy legislation
- Study influence of external sources on legislators
  - Lobbying
  - Donations
  - Testimony

Scope

- Climate and energy bills from 2015 to 2021 in Virginia state legislature

Relevance

- Environmental legislation is important
- Understanding how its made and what affects it is important

Legislative Process

Bill Lifetime

- Introduced to one of the two chambers
- Sent to an appropriate committee
- Voted on the floor
- Sent to an appropriate committee of the other chamber
- Voted on the floor of the other chamber
- Signed by the governor

Bill Death

- 628 bills went to the first committee
- Only 287 bills made it to the first floor
- Over 90% of bill deaths occur in the committee steps

Relaxed Record-Keeping Requirements

- VA ranked 46th in anti-corruption measures (Center of Public Integrity, 2020)
- Lobbyists are not mandated to disclose their positions or payments
- Testimonies are not consistently available

Data

Donors

- Web scraped off Virginia Public Access Project's website
- Every donation to state legislators from 1996 to Fall 2022
- Includes the donor, industry, and amount

Bills

- Every environmental bill from 2015 to 2021
- Includes the committees involved and outcome

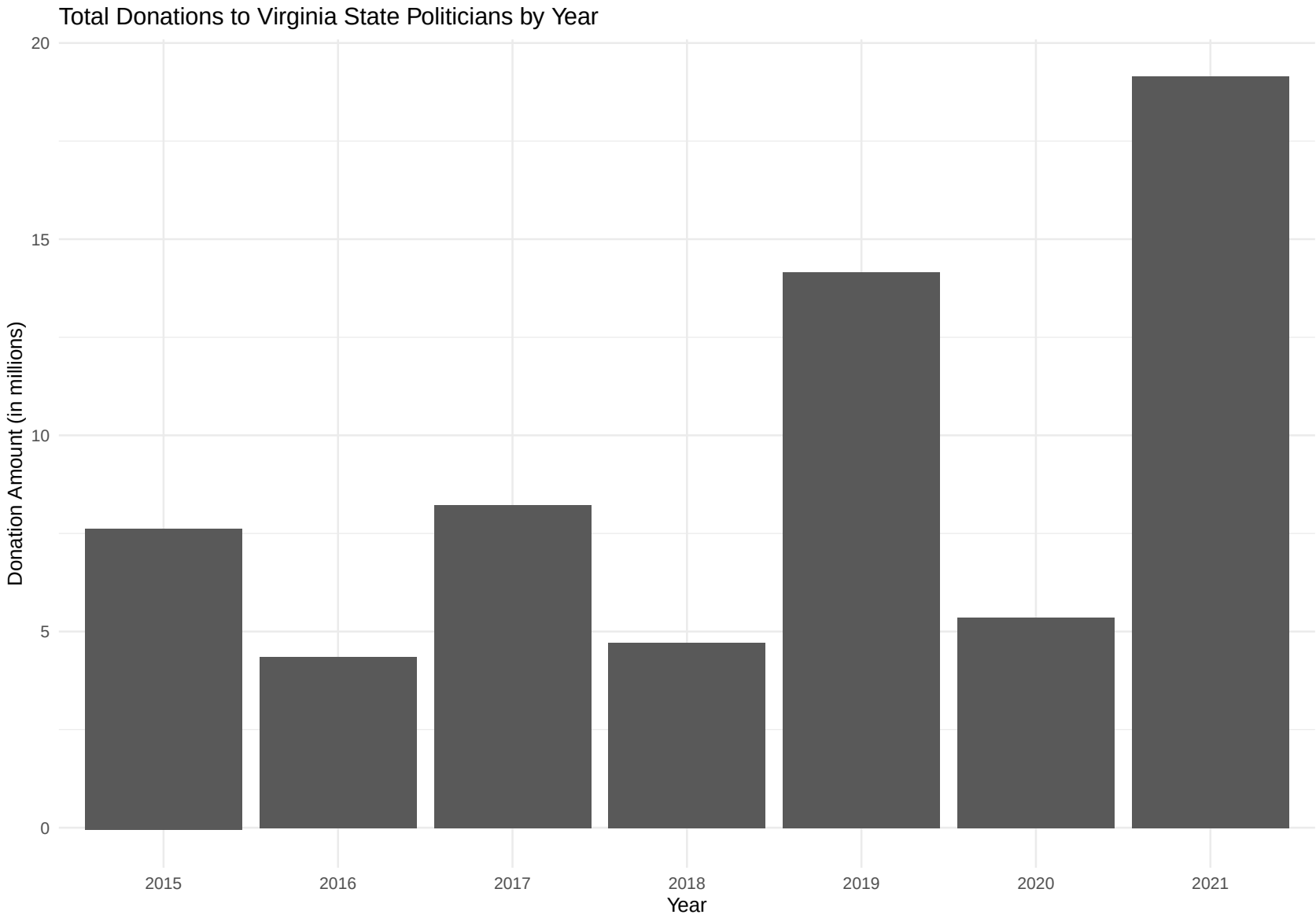
Committees

- Every committee member from 2015 to 2021
- Includes the committee and position in the committee

Politicians

- Every legislator from 2015-2021
- Includes their party, chamber, district, and first year in office

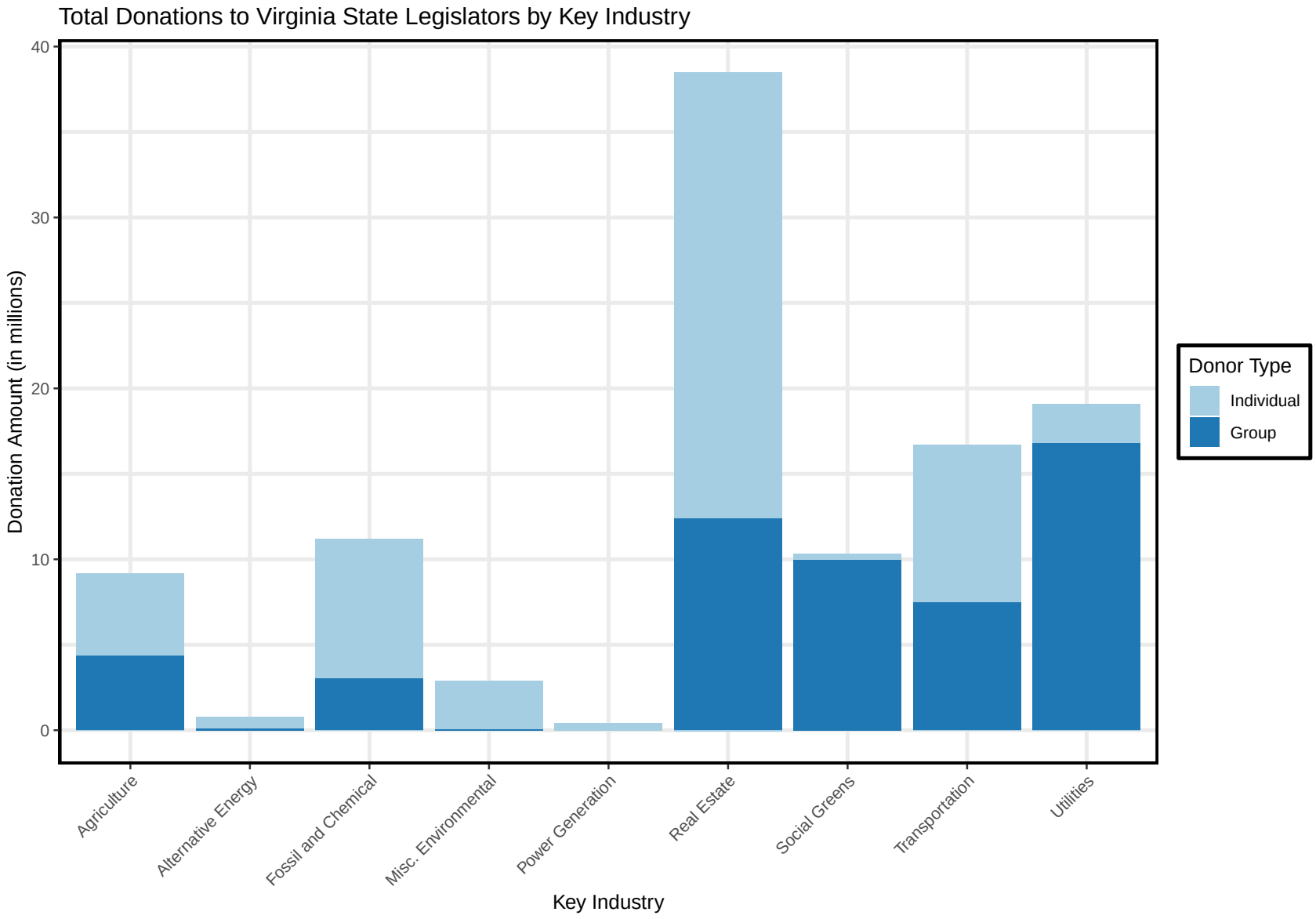
Donations by Year



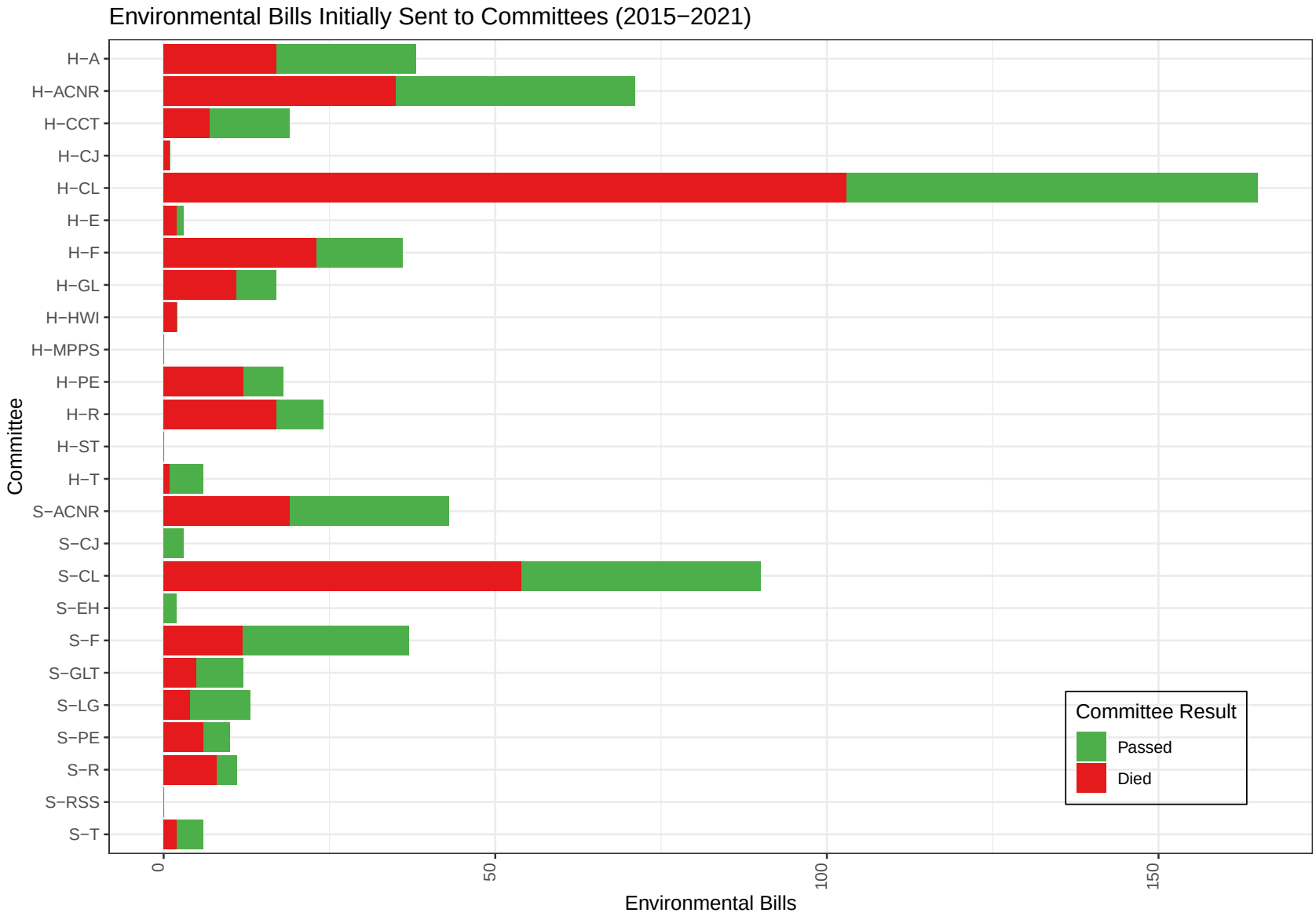
Impactful Donors

- Want to focus less on donations with minimal impact
- Want to focus less on individual district influences
- "Group":
  - Impactful organizations, corporations, and individuals
  - Force: At least $20k in donations to favorite politician
  - Spread: Less than 80% of donations to favorite politician
  - 1.1% of donors, 49.7% of donations

Donations by Key Industry



Bills by Committee



Comparison of Two (Four) Committees

Commerce and Labor (CL)

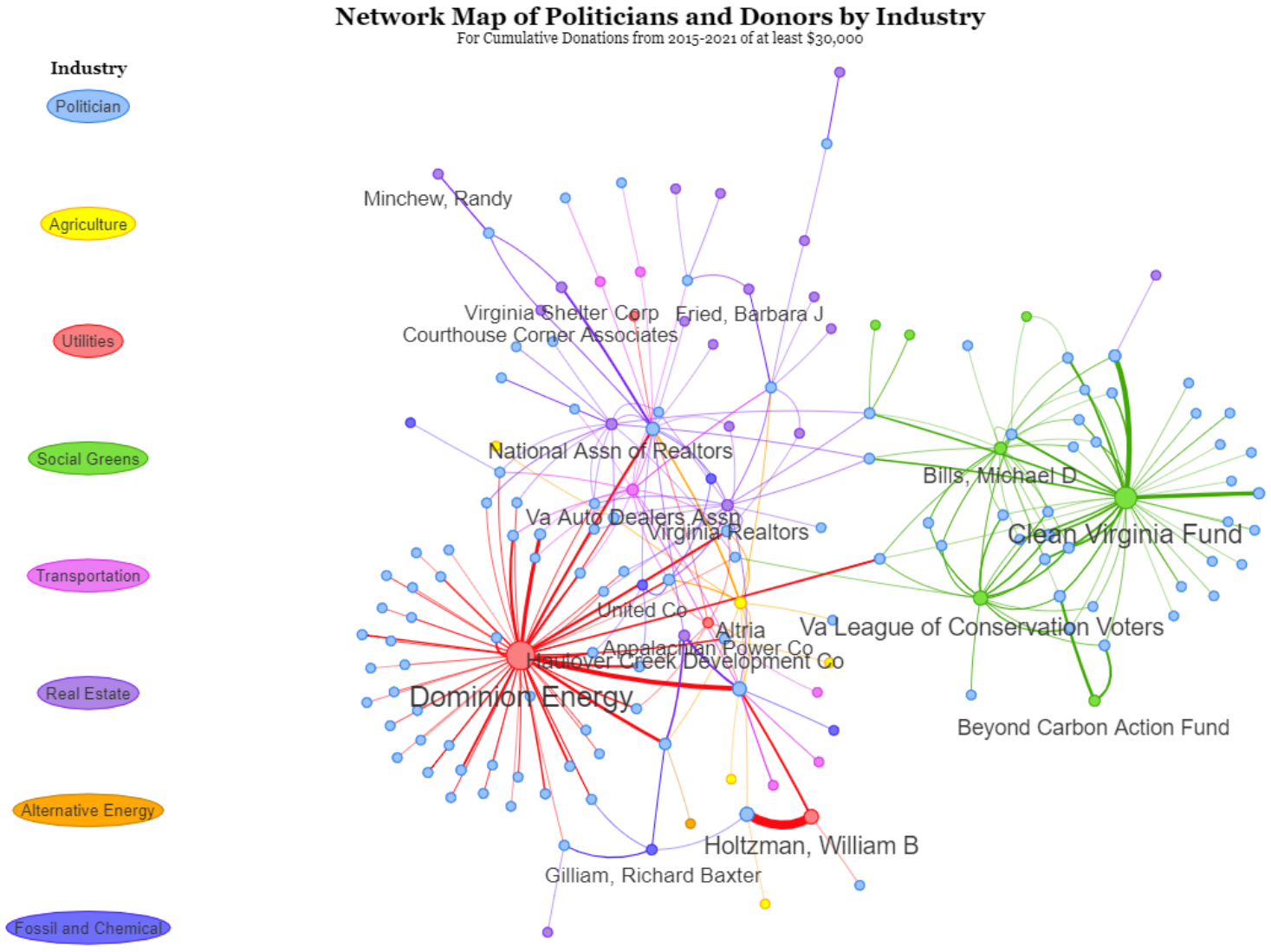
- Senate and House
- 165 bills to House committee
- 90 bills to Senate committee

Agriculture, Conservation & Natural Resources (ACNR)

- Senate and House
- 71 bills to House committee
- 43 bills to Senate committee

	Combined-CL	Combined-ACNR
Mean First Year Elected	2005	2009
Total Donations	$46.2 million	$30.6 million
Dominion Energy Donations	$5.5 million	$3.4 million
Social Greens Donations	$2.6 million	$4.5 million
% Died in Committee (H/S)	62.4%/60.0%	49.3%/44.2%

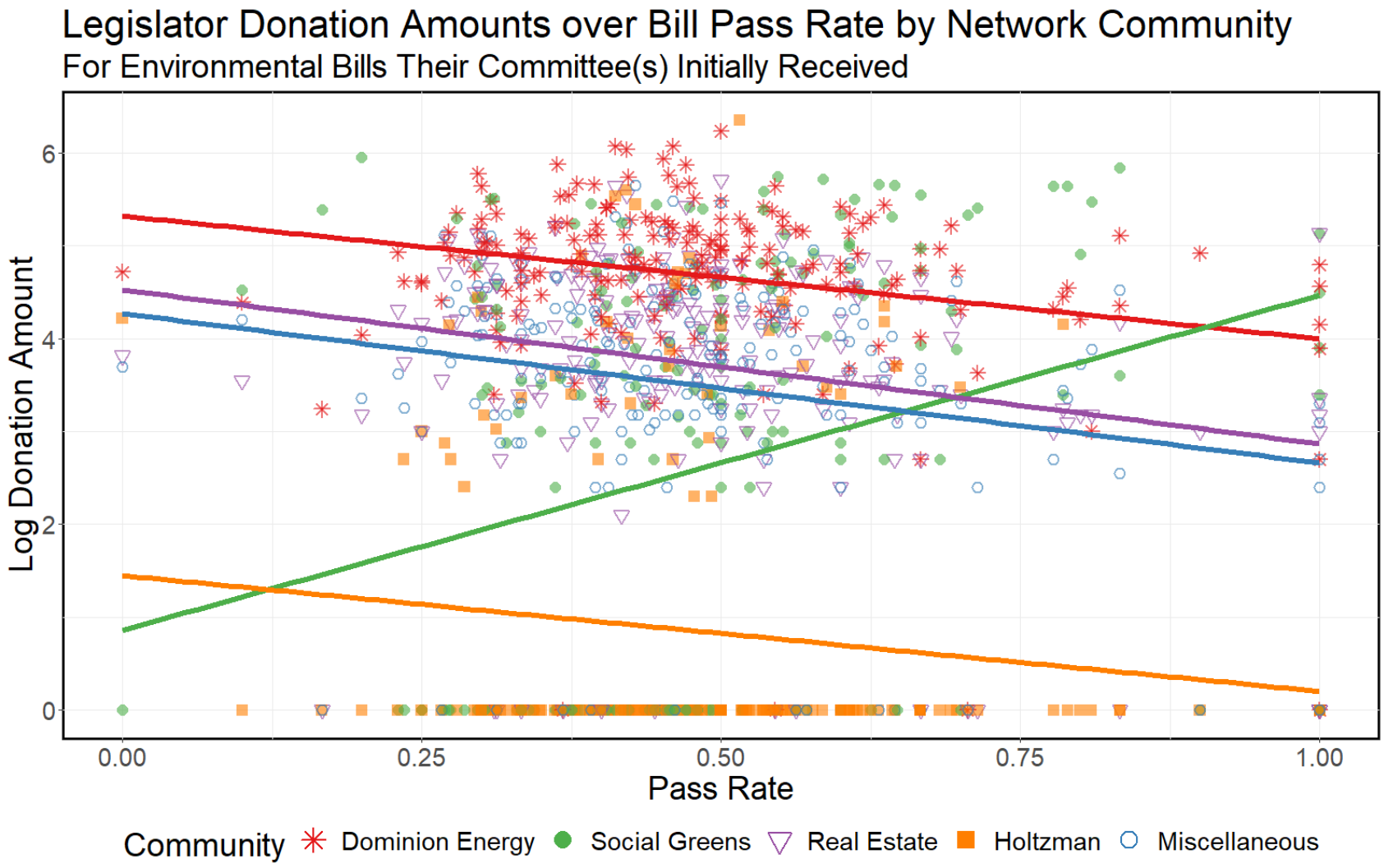
Network Map


Network Map of Politicians and Donors by Industry
For Cumulative Donations from 2015-2021 of at least $30,000
Industry
Politician
Agriculture
Utilities
Social Greens
Transportation
Real Estate
Alternative Energy
Fossil and Chemical
Minchew, Randy
Virginia Shelter Corp
Courthouse Corner Associates
Fried, Barbara J
National Assn of Realtors
Va Auto Dealers Assn
Virginia Realtors
United Co
Altria
Appalachian Power Co
Hanover Creek Development Co
Dominion Energy
Holtzman, William B
Gilliam, Richard Baxter
Bills, Michael D
Clean Virginia Fund
Va League of Conservation Voters
Beyond Carbon Action Fund

Communities

Community	1: Dom. Energy	2: SG	3: Real Est.	4: Holtzman	5: Misc.
Politicians	91	41	30	9	36
Party (D/I/R)	26/1/64	40/0/1	3/0/27	0/0/9	24/0/12
Chamber (H/S)	72/19	35/6	19/11	6/3	22/14
Mean First Year	2010	2016	2006	2009	2003
Donors	21	20	19	9	17
Tot. Donations	$27.8 mil	$11.8 mil	$6.0 mil	$3.8 mil	$4.7 mil

Community Analysis



Conclusion

- 4/5 communities had a negative correlation with the pass rate of environmental bills
- The "Social Greens" community had a positive correlation with the pass rate of environmental bills

Further Research

- More years
- More states
- Committee chairs