USING 2012 STATE CARBON DIOXIDE EMISSIONS AND ANNUAL PAYROLL DATA TO UNDERSTAND UNITED STATES SECTOR EMISSIONS

by

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Executive Summary

The completion of this paper is an excellent summation of my time in the EPC program. I came into the program hoping to compliment my work at the Citizens’ Climate Lobby, which revolves around the implementation of a federal carbon tax and dividend. My time in the EPC program provided the perfect complement of classes, lectures and connections via faculty and students to fill in the gaps in my knowledge between a Biology degree and my current work in energy policy. This capstone is a summation of that new knowledge, combining science in the research and understanding of why this study matters and how it will be relevant to studies in the future, technical knowledge in how to write and format a perfect scientific paper using multiple data sets both researched and calculated, and the policy knowledge of how to combine the knowledge learned into real world implications that can affect future policies regarding decarbonization.

The work in this capstone fits in with the studies I found most interesting during the EPC program (which were policy and energy law classes) through my work and discussion of how decarbonization of sectors may be blocked or aided depending on elected officials. I found that aspect of this study most interesting, as it applies not only to the policy work I do on a daily basis but relates to the history and future prospects for energy policy that I spent time studying and engaging with through the program. I am confident this capstone shows a glimpse into the best of what I have learned and achieved in the EPC program, including the confidence and critical thinking skills needed to excel in my continued career in energy policy and advocacy.
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Introduction

Scope

After decades of increases of carbon dioxide emissions, a result of the industrial revolution and the expansion of industrial processes relying on fossil fuel products, global temperatures continue to rise. (Elliot and Clement 2014) Average land and ocean temperatures have increased 1.9 degrees F since 1880 and resulting effects can be seen and felt across the globe. (Agency 2017)

Partially in response to these warming effects, economic reasons, and the recent emissions reductions goals set through the Paris Climate Accord, decarbonization has now begun throughout the world in primary economic sectors, and continues to grow through supply chains. (Greening the Supply Chain: Best Practices and Future Trends 2012) While the process to decarbonize has been slow at first, many economists, financial institutions, and academics predict the way forward is an economy with less carbon throughout the supply chain and their end products, rather than more. (Victor and Leape 2015) Businesses tout the economic advantages of being able to meet customer demands for clean energy products, as well as acknowledging the future of renewables and ever more expensive fossil fuels. (Benjaafar, Li and Daskin 2012), (Dunn 2012) As climate change impacts continue to be felt more viscerally throughout the world, and warming continues to be recorded, including in the United States, it bears paying attention to how economies will make this enormous switch from fossil fuels to renewables and a far less carbon intensive worldwide economy.
Understanding how industries in the United States currently emit may help to understand the future that we will be facing as decarbonization continues. Existing papers have often worked to understand how to keep track of emissions from industries and sectors, which vary in complexity and ability to track emissions of CO2. This paper aims to look at which sectors and which states within the United States have high emissions and economic influence in the US state economies, in the hope that we can begin to understand where transition and efforts to decarbonize may be felt most, as well as pointing out sectors that may have more political resistance to decarbonize than others due to their impact on the economies of states.

While it is hard to predict exactly how decarbonizing will affect specific industries and sectors, the ability to understand where high emissions overlap with high employment or economic impact may also provide insight into political motivations of elected officials. In addition to exploring this nexus of high employment, high economic impact and potential political resistance, this paper will also aim to point out where data are lacking within these sectors as far as emissions data. Answering the question of whether there are certain sectors within the United States that have high emissions and low economic impact and employment, will potentially serve as a guide to which sectors may be the best “first step” sectors to approach decarbonization efforts.

**Historical Greenhouse Gas Emissions**

The United States has always been a high emitter of greenhouse gases, ever since the industrial revolution which increased the burning of fossil fuels through a variety of sectors of the US economy. (Elliot and Clement 2014) (Agency 2017) Greenhouse gases
add to the warming of the planet, through the capture of carbon dioxide within the atmosphere, a process known as the greenhouse effect. While greenhouse gases are naturally found in the atmosphere, humans have influenced greatly the amount of some of the most potent of those gases. (Agency 2017) Greenhouse gases include carbon dioxide (CO2), methane (CH4), nitrous oxide (N20), as well as water vapor and a few others in smaller amounts. All of the human influenced gases have increased in concentration since the industrial revolution, and now concentrations of CO2 and the others are the highest in recorded history, with current CO2 concentrations at 403.64 as of October, 2017 (up from 280 ppm before the industrial revolution. (Agency 2017), (N. O. Administration n.d.) Additionally, according to the Energy Information Administration (EIA), 78% of the global warming potential comes from carbon dioxide emissions released since 1990 from fossil fuel sources. (Wai and Chong 2016)

The United States remains one of the top three biggest emitters of CO2, along with China and the European Union. (Institute n.d.) (Cragg, et al. 2013) The biggest sector of emissions of carbon dioxide for all of the biggest emitters, and even the smaller, is through energy use, of which fossil fuels still remain the largest part. As of 2009, industries in the United States must report their greenhouse gas emission totals, in order for the Environmental Protection Agency (EPA) to better understand emissions and how to reduce them. (Agency 2017) In 2015, the total amount of greenhouse gas emissions in the United States were 6,586.7 million metric tons of CO2 equivalents. (Agency 2017)

United States emissions and emissions within sectors in those states vary significantly depending on many factors. Within states there can be differing energy sources that an industry or sector may be required to use for the end use product. There
are also differing energy sources available to a state, which may vary due to both policies and resource availability. (Cragg, et al. 2013) Because of the differing sources of energy used in states and sectors, this can change the amount of emissions produced, as a state or source using coal or natural gas will have higher emissions than one using solar or hydropower. Differences in climate and weather can also impact the amount of energy an industry or state uses, especially when looking at residential uses of energy such as home heating. States with milder climates have less extreme weather swings than states with larger variances, which can impact the amount of energy used during different seasons. (Cragg, et al. 2013)

The EIA keeps track of various data points regarding state emissions. This includes total state emissions levels, and the changes within those levels. Their most recent report has data up to 2014, with state emissions decreasing in 35 states and increasing in the remaining states over a 14-year period. (Cragg, et al. 2013) Two important data measurements that EIA tracks in regard to emissions and economic output, are its measurements of “carbon intensity of the energy supply” and “carbon intensity of the economy”. Both of these deal with the energy supply mix within a state, as well as the difference in amounts of CO2 that come from using different energy sources (coal versus natural gas, for example). Carbon intensity of the economy deals with energy intensity of the economy of the state. This means looking at how energy intensive the CO2 per dollar of state GDP is. (Cragg, et al. 2013) (Dietz, et al. 2014)

Carbon dioxide emissions can come from non-energy uses as well. This includes processes in agriculture and land use as well as during the manufacturing of a product where carbon dioxide is released as a byproduct. Most carbon used in non-energy
purposes however, end up stored in the product. EIA data states that 62% of total carbon used for non-energy purposes ends up stored, while only 38% end up emitted. (Agency 2017) (Institute n.d.)

**Emissions and Carbon Reducing Policies**

Many countries, including the United States have tried various attempts at regulating emissions of greenhouse gases, all with differing success rates. The United States differs from other countries in its attempts, due to a massive political roadblock. The United States is the only developed western country that continues to have a large number of its population, and a majority of one of its major political parties deny that climate change and global warming are occurring and due to human activities. (Milman 2015) This complicates the work of attempting to get long lasting, economy wide solutions to CO2 emissions and regularly brings into question the idea of the trade-offs of environmental versus economic policy.

Historically, party affiliation has been a major deciding factor in how votes on carbon reducing policies were determined. There have been a few studies looking at other reasons why Congressional representatives vote the way they do, with at least one pointing to affluence of constituents as well as self-interest and emissions intensity of industries in their district. (Dietz, et al. 2014) This paper hypothesizes that looking at industry sector emissions by state will reveal similar associations; that states whose sectors have high emissions and high economic reliance on CO2 emissions will also generally be governed by Republicans, who have historically been against emissions reducing policies.
Industry efforts to Reduce Carbon Emissions and Future Prospects

Efforts by industry and business to decarbonize often depend on multiple factors including how feasible, economic, and necessary it is for them to do so. There have been studies attempting to understand motivations behind those that are making switches to decarbonized energy sources for production, with numerous factors playing roles in decision making. One such factor is how cheap it is to make the switch and the benefits to the company for doing so. Industries with high emissions may try to relocate themselves to other areas of the United States where it is cheaper to produce products with decarbonized energy supply (through renewables or other fossil fuels with lower carbon intensity), especially if they have an incentive to do so. (Denis-Ryan, Bataille and Jotzo 2016) (Milman 2015) Other ways that industry and individual businesses have worked to reduce emissions have been in the forms of internal carbon pricing, buying carbon offsets, or using the celebrity and attention of high level CEOs and business leaders to encourage fighting climate change. (Ormond 2015)

There have been more and more companies both in the US and worldwide working to reduce emissions through these methods. The continuing commitment to reductions, despite recent setbacks at the federal level in the United States, serve as an example for other businesses who may want to start thinking about decarbonization. Walmart, Facebook, Google, Microsoft, and many others have committed to reducing their carbon footprints through many of the mechanisms mentioned above, and have shown that larger companies are capable of carbon reductions throughout their supply chain. (Ormond 2015) (Bettenhausen, Byrd and Cooperman 2014)
While there is currently no mandatory reporting of greenhouse gas emissions by most private companies as far as greenhouse gas emissions, there have been attempts to track companies who voluntarily allow tracking of their data. The biggest collection of such work has been done by the Carbon Disclosure Project. The CDP has been working to gather information from businesses around the world since 2008, hoping to provide insight into emissions levels that otherwise have been hard to report on. (Bettenhausen, Byrd and Cooperman 2014)

This paper hopes to contribute to the vast amount of knowledge around how industry and states’ economic sectors can begin to reduce emissions. First by understanding what emissions and economic data can be used to discover how best to get to the emissions reductions needed. Through experimenting with new methods for evaluating the economic link between emissions and sectors across states, I hope to bring some new light to this effort.

**Methods**

In an effort to understand how employment and emissions data could be looked at comparatively, this paper used two major data sets from the US government. There was plenty of employment data available, as well as other economic statistics through the US Census Bureau that I hypothesized could potentially work as a way to estimate emissions by sector and the impact on employment in the states since there is no direct data on emissions down to the sector specific level. Through this I decided I needed to come up with a ratio in order to make these estimates work and as closely as possible reflect what was trying to be determined.
To do this, I decided to use Annual Payroll data from the US Census Bureau, which had most recently available data from 2012. Combining the annual payroll data with emissions data from the Energy Information Administration of the United States, I was able to get emissions data from 2012 for each of the 50 states. (U. E. Administration, State Carbon Dioxide Emissions Data 2017) The data from EIA used was the “State Carbon Dioxide Emissions from Fossil Fuel Consumption (1980-2015). I used each state’s total quantity of emissions in millions of metric tons as recorded for the year 2012 in order to match the economic data most recently available from the US Census.

I proceeded to use the yearly carbon dioxide emissions data from the United States total in 2012 and divided that by the total US annual Payroll for all sectors in 2012 in order to come up with an “emissions per payroll dollar ratio” (EPPDR) for the United States. This equation came out to:

Total US Annual Payroll 2012 (269,069,624,000) / Total US Carbon Emissions 2012 (6,538,276,080.00) = 0.02429957

This estimated that for every $1 dollar was paid to a US employee in one of these sectors, .02 metric tons of CO2 was emitted in 2012. There are some obvious problems with simplifying emissions data to an equation like this, but because of an extreme lack of data beyond the four big buckets of carbon emissions (commercial, residential, transportation, energy), finding a way to estimate a more granular look at emissions by sector was required. I realized that annual payroll is a good way to do this, since it not only accounts for number of employees, but also accounts for the difference in jobs and
their impact on the GDP for each economy of the states. As stated in a paper published in Economic Development Quarterly, “…payroll, is a measure of output that includes all forms of compensation, such as salaries, wages, commissions, bonuses and the value of taxable fringe benefits. Trends in payroll are relatively reliable indicator of the overall economic output. As firms expand or more firms locate in a region, overall payroll should increase.” (Thomas 2009) By using payroll data, I hoped to account for the economic impact of sectors beyond simply the number of employees, which would just create the result that more employees equals more emissions.

The economic data used was from the US Census Bureau’s American Fact Finder database. (Bureau n.d.) For each NAICS code (North American Industry Classification System) I used the “All sectors: Geographic Area Series: Economy-Wide Key Statistics: 2012” and created data spreadsheets for each state, selected NAICS code sectors within that state, as well as total emissions per state and total payroll per state. The NACIS code used were the following, with descriptions of what they include. Descriptions are based off of the NAICS website which is part of the US Census Bureau’s North American Industry Classification System. (Bureau n.d.)

**Utilities (22):** The Utilities sector comprises establishments engaged in the provision of the following utility services: electric power, natural gas, steam supply, water supply, and sewage removal. Within this sector, the specific activities associated with the utility services provided vary by utility: electric power includes generation, transmission, and distribution; natural gas includes distribution; steam supply includes provision and/or distribution; water supply includes treatment and distribution; and sewage removal includes collection, treatment, and disposal of waste through sewer systems and sewage
treatment facilities. Excluded from this sector are establishments primarily engaged in waste management services classified in Subsector 562, Waste Management and Remediation Services. These establishments also collect, treat, and dispose of waste materials; however, they do not use sewer systems or sewage treatment facilities.

**Oil and Gas Extraction (211):** Oil and gas extraction includes oil and gas extraction of crude petroleum and natural gas extracting as well as natural gas liquid extraction. Does not include support activities for oil and gas extraction or drilling for mines and wells.

**Mining (212):** Mining (except oil and gas) includes coal mining, both bituminous coal and lignite surface mining as well as bituminous coal underground mining, anthracite mining, metal ore mining, nonmetallic mineral mining and quarrying. Does not include support activities for mining (these fall under 213).

**Construction (23):** The Construction sector comprises establishments primarily engaged in the construction of buildings or engineering projects (e.g., highways and utility systems). Establishments primarily engaged in the preparation of sites for new construction and establishments primarily engaged in subdividing land for sale as building sites also are included in this sector. Establishments primarily engaged in contracts that include responsibility for all aspects of individual construction projects are commonly known as general contractors, but also may be known as design-builders, construction managers, turnkey contractors, or (in cases where two or more establishments jointly secure a general contract) joint-venture contractors. Construction managers that provide oversight and scheduling only (i.e., agency) as well as construction managers that are responsible for the entire project (i.e., at risk) are included as general contractor type establishments. Establishments of the "general contractor type" frequently
arrange construction of separate parts of their projects through subcontracts with other construction establishments.

Establishments primarily engaged in activities to produce a specific component (e.g., masonry, painting, and electrical work) of a construction project are commonly known as specialty trade contractors. Activities of specialty trade contractors are usually subcontracted from other construction establishments, but especially in remodeling and repair construction, the work may be done directly for the owner of the property.

**Retail Trade (44-45):** Retail trade includes all retail trade categories. This includes motor vehicle parts and dealers, automobile dealers, furniture and home furnishing stores, electronics and appliance stores, building material and garden equipment and supplies dealers, lawn and garden equipment and supplies stores, food and beverage stores, health and personal care stores, and gasoline stations including their convenience stores, clothing and accessories stores, jewelry, luggage and leather goods stores, sporting goods, books, hobby and musical stores, miscellaneous store retailers, office supplies, and non-store retailers including vending machine operators and direct selling establishments.

**Manufacturing (31-33):** Manufacturing includes the following categories: Food manufacturing, Beverage and tobacco product manufacturing, Textile manufacturing, apparel manufacturing, Wood Product manufacturing, Paper Manufacturing, Printing and Related Support Activities, Petroleum and Coal Products Manufacturing, Chemical Manufacturing, Plastics and Rubber Products Manufacturing, Nonmetallic Mineral Product Manufacturing, Primary Metal Manufacturing, Fabricated Metal Product Manufacturing, Machinery Manufacturing, Computer and Electronic Product Manufacturing, Electrical Equipment, Appliance and Component Manufacturing,
Transportation and Warehousing (48-49): Transportation and Warehousing includes the following: Air Transportation, Rail Transportation, Water Transportation, Truck transportation, Transit and Ground Passenger Transportation, Pipeline Transportation, Scenic and sightseeing transportation, Support Activities for Transportation, Postal Service, Couriers and Messengers, Warehousing and Storage

Each NAICS code sector has a report through the US Census Bureau that includes the Annual Payroll amount for the individual sectors listed above. I took the total annual payroll of each state and divided that by each states’ annual carbon dioxide emissions in 2012 to come up with each states’ “emissions per payroll dollar ratio” (EPPDR). This number was then multiplied by each sector’s annual payroll (Mining, Oil and Gas, Construction, Retail Trade, Wholesale Trade, Manufacturing, Transportation and Warehousing and Utilities) within that state in order to come up with the estimated quantity of emissions per sector per state. I did this for each of the 50 US states and each of the eight sectors mentioned above in order to come up with state profiles (Graphs 1-50). Some states were recorded as 0 because the data for payroll in those states was listed as “Withheld to avoid disclosing data for individual companies; data are included in
higher level totals” in which case I was unable to account for the payroll amount. These states are pointed out in graphs where they are listed as 0.

Additionally, each sector was separated out and graphed for all states to show comparisons of emissions in each sector and across states. These can be seen in Graphs 52-59. In addition to the emissions and payroll data, for each of these graphs, I also included colors to represent whether each state was governed by a Democrat (blue) or a Republican (red) in 2012 in order to help draw conclusions about the possible policy implications for the results seen.

Using payroll and emissions in a simplified fashion such as in this paper has caveats. The missing factors in using payroll is that there is no accounting for differences by state as far as energy uses, such as renewables or intensity of the fossil fuels used (other than just more emissions released), as well as that jobs that are valued as more “useful” will impact the payroll number, jobs deemed more “useful” such as high-level jobs (lawyer, doctor, etc.) have higher value when data is tabulated. NAICS data separates out industries in a very different way than how emissions are currently tracked, which contributes to some difficulty in matching results of NAICS sector emissions and traditional emissions records. Until we can track emissions down to much more specific industry levels, the ability to understand emissions from industry and how to reduce them will be limited, and even more so when investigating how jobs and employment will change with reductions in emissions in those industries.

A more in-depth study, or with more accurate data (that is currently lacking) would be able to draw much more specific and accurate conclusions from multiple sets of data, rather than the two sources used here and the estimates developed here.
Additionally, this calculation also misses out on contributions of agriculture, as that is not included in the emissions data of EIA, nor at the payroll level (farm level jobs are excluded from annual payroll). Agriculture emissions are a significant part of the United States emissions at around 9% in 2015 and so it is unfortunate to have to leave it out of this study, but until better data can be tracked and reported, it is not possible to compare emissions and payroll data of agriculture sectors. (U. S. Agency 2015)

**Results**

Results for each state can be seen in the following graphs. Each states payroll emissions profile shows the estimated emissions for the sectors of Mining, Oil and Gas, Construction, Retail Trade, Wholesale Trade, Manufacturing, Transportation and Utilities through annual payroll back-estimates. These are represented by bar graphs in order to show which sector in each state had the highest and lowest estimated emissions.
For Alabama (Graph 1) results showed that Manufacturing had the highest estimated emissions of the eight industries looked at, with 17,030,942 metric tons of CO2. Oil and Gas had the lowest, with 95,151 metric tons of CO2.

Graph 1. Alabama carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Alaska (Graph 2) results showed that Construction had the highest emissions of the eight industries looked at, with 3,270,990 metric tons of CO2. Mining had the lowest, with 520,147 metric tons.

Graph 2. Alaska carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Arizona (Graph 3) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 6,811,939 metric tons of CO2. Oil and Gas had the lowest, with 5,526 metric tons of CO2.

Graph 3. Arizona carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Arkansas (Graph 4) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 9,187,388 metric tons of CO2. Mining had the lowest, with 5,526 metric tons.

Graph 4. Arkansas carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For California (Graph 5) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 26,105,587 metric tons of CO2. Oil and Gas had the lowest, with 34,941 metric tons of CO2.

Graph 5. California carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Colorado (Graph 6) results showed that Retail Trade had the highest emissions of the eight industries looked at, with 4,648,954 metric tons of CO2. Mining had the lowest, with 290,939 metric tons of CO2.

Graph 6. Colorado carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Connecticut (Graph 7) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 3,450,751 metric tons of CO2. Oil and Gas had the lowest, with 0 metric tons of CO2.

Graph 7. Connecticut carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Delaware (Graph 8) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 3,450,751 metric tons of CO2. Mining and Oil and Gas tied for the lowest, with 0 metric tons of CO2. Mining data for Delaware is listed as “withheld to avoid disclosing data for individual companies, data are included in higher level totals” in US Census Bureau data.

Graph 8. Delaware carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012. Mining data for Delaware is listed as “withheld to avoid disclosing data for individual companies, data are included in higher level totals” in US Census Bureau data.
For District of Columbia (Graph 9) results showed that Retail Trade had the highest emissions of the eight industries looked at, with 27,988 metric tons of CO2. Mining, Oil and Gas and Utilities tied for the lowest, with 0 metric tons of CO2.

Graph 9. District of Columbia carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Florida (Graph 10) results showed that Retail Trade had the highest emissions of the eight industries looked at, with 14,698,231 metric tons of CO2. Oil and Gas had the lowest, with 4,199 metric tons of CO2.

Graph 10. Florida carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Georgia (Graph 11) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 11,877,253 metric tons of CO2. Oil and Gas had the lowest, with 0 metric tons of CO2.

Graph 11. Georgia carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Hawaii (Graph 12) results showed that Retail Trade had the highest emissions of the eight industries looked at, with 1,465,832 metric tons of CO2. Mining had the lowest, with 0 metric tons of CO2.

Graph 12. Hawaii carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Idaho (Graph 13) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 1,807,808 metric tons of CO2. Oil and Gas had the lowest, with 415 metric tons of CO2.

Graph 13. Idaho carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Illinois (Graph 14) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 18,646,681 metric tons of CO2. Oil and Gas had the lowest, with 44,435 metric tons of CO2.

Graph 14. Illinois carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Indiana (Graph 15) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 35,719,638 metric tons of CO2. Oil and Gas had the lowest, with 4,199 metric tons of CO2.

Graph 15. Indiana carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Iowa (Graph 16) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 12,957,236 metric tons of CO2. Oil and Gas had the lowest, with 0 metric tons of CO2.

Graph 16. Iowa carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Kansas (Graph 17) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 8,415,294 metric tons of CO2. Mining had the lowest, with 55,024 metric tons of CO2.

Graph 17. Kansas carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Kentucky (Graph 18) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 19,335,212 metric tons of CO2. Oil and Gas had the lowest, with 143,777 metric tons of CO2.

Graph 18. Kentucky carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Louisiana (Graph 19) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 21,690,347 metric tons of CO2. Mining had the lowest, with 193,829 metric tons of CO2.

Graph 19. Louisiana carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Maine (Graph 20) results showed that Manufacturing had the highest estimated emissions of the eight industries looked at, with 1,601,320 metric tons of CO2. Oil and Gas had the lowest, with 0 metric tons of CO2.

Graph 20. Maine carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Maryland (Graph 21) results showed that Construction had the highest emissions of the eight industries looked at, with 3,674,478 metric tons of CO2. Oil and Gas had the lowest, with 0 metric tons of CO2.

Graph 21. Maryland carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Massachusetts (Graph 22) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 3,907,563 metric tons of CO2. Mining and Oil and Gas had the lowest, with 0 metric tons of CO2. Mining data for Massachusetts is listed as “withheld to avoid disclosing data for individual companies, data are included in higher level totals” in US Census Bureau data.

Graph 22. Massachusetts carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012. Mining data for Massachusetts is listed as “withheld to avoid disclosing data for individual companies, data are included in higher level totals” in US Census Bureau data.
For Michigan (Graph 23) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 22,777,180 metric tons of CO2. Oil and Gas had the lowest, with 55,586 metric tons of CO2.

Graph 23. Michigan carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Minnesota (Graph 24) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 9,656,035 metric tons of CO2. Oil and Gas had the lowest, with 510 metric tons of CO2.

Graph 24. Minnesota carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Mississippi (Graph 25) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 9,383,566 metric tons of CO2. Mining had the lowest, with 51,102 metric tons of CO2.

Graph 25. Mississippi carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Missouri (Graph 26) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 12,129,370 metric tons of CO2. Oil and Gas had the lowest, with 3,610 metric tons of CO2.

Graph 26. Missouri carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Montana (Graph 27) results showed that Retail Trade had the highest emissions of the eight industries looked at, with 2,556,999 metric tons of CO2. Oil and Gas had the lowest, with 185,644 metric tons of CO2.

Graph 27. Montana carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Nebraska (Graph 28) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 4,855,984 metric tons of CO2. Mining had the lowest, with 0 metric tons of CO2. Mining data for Nebraska is listed as “withheld to avoid disclosing data for individual companies, data are included in higher level totals” in US Census Bureau data.

Graph 28. Nebraska carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012. Mining data for Nebraska is listed as “withheld to avoid disclosing data for individual companies, data are included in higher level totals” in US Census Bureau data.
For Nevada (Graph 29) results showed that Retail Trade had the highest estimated emissions of the eight industries looked at, with 2,424,221 metric tons of CO2. Oil and Gas had the lowest, with 1,812 metric tons of CO2.

Graph 29. Nevada carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For New Hampshire (Graph 30) results showed that Manufacturing had the highest estimated emissions of the eight industries looked at, with 1,849,908 metric tons of CO2. Oil and Gas had the lowest, with 0 metric tons of CO2.

Graph 30. New Hampshire carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For New Jersey (Graph 31) results showed that Wholesale Trade had the highest emissions of the eight industries looked at, with 8,622,606 metric tons of CO2. Oil and Gas had the lowest, with 0 metric tons of CO2.

Graph 31. New Jersey carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For New Mexico (Graph 32) results showed that Retail Trade had the highest emissions of the eight industries looked at, with 3,813,980 metric tons of CO2. Mining had the lowest, with 471,546 metric tons of CO2.

Graph 32. New Mexico carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For New York (Graph 33) results showed that Retail Trade had the highest emissions of the eight industries looked at, with 6,576,242 metric tons of CO2. Oil and Gas had the lowest, with 26,368 metric tons of CO2.

Graph 33. New York estimated emissions in metric tons using annual payroll and state emissions levels in 2012.
For North Carolina (Graph 34) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 14,698,231 metric tons of CO2. Mining and Oil and Gas had the lowest, with 0 metric tons of CO2. North Carolina Mining and Oil and Gas were both listed in the US Census Bureau NAICS data as “Withheld to avoid disclosing data for individual companies; data are included in higher level totals”.

![North Carolina emissions in metric tons using payroll data (2012)](image)

Graph 34. North Carolina carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012. Mining and Oil and Gas were both listed in the US Census Bureau NAICS data as “Withheld to avoid disclosing data for individual companies; data are included in higher level totals”.

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For North Dakota (Graph 35) results showed that Construction had the highest emissions of the eight industries looked at, with 3,758,809 metric tons of CO2. Utilities had the lowest, with 0 metric tons of CO2.

Graph 35. North Dakota carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Ohio (Graph 36) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 28,822,014 metric tons of CO2. Oil and Gas had the lowest, with 68,926 metric tons of CO2.

Graph 36. Ohio estimated emissions in metric tons using annual payroll and state emissions levels in 2012.
For Oklahoma (Graph 37) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 9,852,313 metric tons of CO2. Mining had the lowest, with 135,682 metric tons of CO2.

Graph 37. Oklahoma carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Oregon (Graph 38) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 4,657,482 metric tons of CO2. Oil and Gas had the lowest, with 191 metric tons of CO2.

Graph 38. Oregon carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Pennsylvania (Graph 39) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 22,147,074 metric tons of CO2. Oil and Gas had the lowest, with 568,392 metric tons of CO2.

Graph 39. Pennsylvania carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Rhode Island (Graph 40) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 979,808 metric tons of CO2. Oil and Gas had the lowest, with 0 metric tons of CO2.

Graph 40. Rhode Island carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For South Carolina (Graph 41) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 10,220,120 metric tons of CO2. Oil and Gas had the lowest, with 0 metric tons of CO2.

Graph 41. South Carolina carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For South Dakota (Graph 42) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 1,711,154 metric tons of CO2. Oil and Gas had the lowest, with 2,641 metric tons of CO2.

Graph 42. South Dakota carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Tennessee (Graph 43) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 12,145,919 metric tons of CO2. Oil and Gas had the lowest, with 9,429 metric tons of CO2.

Graph 43. Tennessee carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Texas (Graph 44) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 45,891,014 metric tons of CO2. Mining had the lowest, with 492,845 metric tons of CO2.

Graph 44. Texas carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Utah (Graph 45) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 6,849,148 metric tons of CO2. Oil and Gas had the lowest, with 225,059 metric tons of CO2.

Graph 45. Utah estimated carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Vermont (Graph 46) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 726,338 metric tons of CO2. Oil and Gas and Utilities had the lowest, with 0 metric tons of CO2.

Graph 46. Vermont estimated carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Virginia (Graph 47) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 5,330,616 metric tons of CO2. Oil and Gas had the lowest, with 9,248 metric tons of CO2.

Graph 47. Virginia estimated carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Washington (Graph 48) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 6,951,662 metric tons of CO2. Oil and Gas had the lowest, with 0 metric tons of CO2.

Graph 48. Washington estimated carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For West Virginia (Graph 49) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 8,472,948 metric tons of CO2. Oil and Gas had the lowest, with 635,994 metric tons of CO2.

Graph 49. West Virginia estimated carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Wisconsin (Graph 50) results showed that Manufacturing had the highest emissions of the eight industries looked at, with 15,643,595 metric tons of CO2. Oil and Gas had the lowest, with 0 metric tons of CO2.

Graph 50. Wisconsin estimated carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
For Wyoming (Graph 51) results showed that Construction had the highest emissions of the eight industries looked at, with 3,638,803 metric tons of CO2. Utilities had the lowest, with 1,172,962 metric tons of CO2.

Graph 51. Maine estimated carbon dioxide emissions per sector in metric tons using annual payroll data of each sector to back calculate estimated state emissions per sector in 2012.
Results comparing each industry across all states for the eight NAICS codes investigated are shown below. Each graph shows emissions in metric tons. Each graph also shows the political affiliation of the Governor of the state in 2012. Bars in red had a Republican Governor and bars in blue had a Democratic Governor at the time this data was recorded (2012).

(Graph 52) shows that Texas dominates the Oil and Gas sector emissions across states with 6,884,173 estimated metric tons of CO2. Wyoming and Louisiana are second and third with 2,721,042 and 1,841,420 metric tons respectfully. States with the lowest number include those with no reported Oil and Gas emissions and North Carolina, where data was “withheld to avoid disclosure of data for individual companies”.

![Oil and Gas emissions in metric tons using payroll data by State (2012)](image-url)
Graph 52. Graph shows Oil and Gas sector carbon dioxide estimated emissions using payroll data for 2012 across all states. Red bars show states governed by Republicans in 2012, blue bars are Democratic governed states in 2012. North Carolina data from US Census Bureau was “withheld to avoid disclosure for individual companies”.

For Mining sector by state (Graph 53), West Virginia and Wyoming are the top two states at 6,411,436 metric tons of CO2 and 4,599,130 metric tons with Kentucky in third at 2,176,858 metric tons of CO2. Delaware, Massachusetts, Nebraska and North Carolina all had data “withheld to avoid disclosing data for individual companies” per the US Census Bureau. Two out of the three top ranking emitters by state (Kentucky and West Virginia) were governed by Democrats in 2012 at the time the economic data was recorded.
Graph 53. Graph shows Mining sector carbon dioxide estimated emissions using payroll data for 2012 across all states. Red bars show states governed by Republicans in 2012, blue bars are Democratic governed states in 2012. Delaware, Massachusetts, Nebraska and North Carolina all had data “withheld to avoid disclosing data for individual companies” per the US Census Bureau.

For Construction Emissions by State (Graph 54), Texas dominates with 30,042,513 metric tons of CO2 with Louisiana in second at 18,699,824 metric tons and California following with 11,454,239 metric tons. Two out of the three top emitters (Texas and Louisiana) were governed by Republicans in 2012 when this data was recorded.
Graph 54. Graph shows Construction sector carbon dioxide estimated emissions using payroll data for 2012 across all states. Red bars show states governed by Republicans in 2012, blue bars are Democratic governed states in 2012.

For Retail Trade Payroll Emissions by State (Graph 55), Texas had the highest with 31,114,437 metric tons of CO2. California followed with 16,330,328 metric tons and Florida with 14,698,231 metric tons. Two out of the three top emitters (Texas and Florida) were governed by a Republican in 2012 when the data was recorded.
Graph 55. Graph shows Retail Trade sector carbon dioxide estimated emissions using payroll data for 2012 across all states. Red bars show states governed by Republicans in 2012, blue bars are Democratic governed states in 2012.

For Wholesale Trade Payroll Emissions by State, (Graph 56), Texas was the highest with 33,939,781 metric tons of CO2 emissions. Califronia was second highest with 22,128,021 metric tons and Illinois was third with 13,515,932 metric tons. Two out of the three highest emitters (California and Illinois) were governed by a Democrat in 2012 at the
time this data was recorded.

Graph 56. Graph shows Wholesale Trade sector carbon dioxide estimated emissions using payroll data for 2012 across all states. Red bars show states governed by Republicans in 2012, blue bars are Democratic governed states in 2012.

For Manufacturing Payroll Emissions by State (Graph 57), Texas was the highest with 45,891,014 metric tons of CO2. Second was Indiana with 35,719,638 metric tons and
Ohio with 28,822,014 metric tons. Two out of the three highest emitters (Texas and Indiana) were governed by a Republican in 2012 at the time this data was recorded.

Graph 57. Graph shows Manufacturing sector carbon dioxide estimated emissions using payroll data for 2012 across all states. Red bars show states governed by Republicans in 2012, blue bars are Democratic governed states in 2012.

For Transportation Payroll Emissions by State (Graph 58), Texas was the highest with
20,724,661 metric tons of CO2. The second highest was Louisiana with 9,655,378 metric tons and third was California with 7,425,344 metric tons. Two out of the three highest emitters (Texas and Louisiana) were governed by a Republican in 2012 at the time this data was recorded.

Graph 58. Graph shows Transportation sector carbon dioxide estimated emissions using payroll data for 2012 across all states. Red bars show states governed by Republicans in 2012, blue bars are Democratic governed states in 2012.
For Utilities Payroll Emissions by State (Graph 59), Texas was the highest, with 4,820,254 metric tons of CO2. Second was California with 2,639,994 metric tons and third was Pennsylvania with 2,416,363 metric tons. Two out of the three highest emitters (Texas and Pennsylvania) were governed by a Republican in 2012, at the time this data was recorded.

Graph 59. Graph shows Utilities sector carbon dioxide estimated emissions using payroll data for 2012 across all states. Red bars show states governed by Republicans in 2012, blue bars are Democratic governed states in 2012.
Discussion

In attempting to understand how emissions and employment and economic impacts relate together by industry in the United States, perhaps the single greatest conclusion I came to was that until data can be reliably and consistently recorded from all industries, this question is difficult to answer. Understanding how industries and sectors use, consume and emit, are all questions that have been attempted to be answered many times over, but when it comes to a database of basic emissions totals by specific industry or sector, the glaring lack of information leads one to wonder how we can work to lower emissions effectively without knowing what the baseline of emissions currently are. It also leads to a lack of understanding of where political pushback can be expected as elected officials will respond to the demands of their economically impactful sectors.

By using payroll and emissions data, I hoped to find new insights into which sectors in each state have larger impacts on emissions and state employment and answer the question of whether there are certain industries within the United States that have high emissions and low economic impact and employment, and would serve as best “first step” industries to approach decarbonization efforts. My results offer insight into this question, but I do not believe offer enough specificity due to the need to estimate emissions, to accurately tease out the nuances needed to answer this question with a high degree of confidence. I do believe the results are one piece in the puzzle that can be used to answer this question, and continued research into techniques to estimate emissions or efforts to get more accurate emissions data recorded would add to the answer.

Whether the data I came up with can be used to determine where to best first aim
to reduce emissions is a hard question, especially since emissions levels have changed greatly since 2012, but I believe at the very least, that my results show using payroll data can offer interesting insights into estimated sector emissions across states, and offer a better understanding of how much more intricate calculations with multiple inputs would be needed to be to really tease out which industries or sectors are ripe for decarbonization from an employment and economic impacts perspective. I also believe that my method could be improved by being replicated in the coming years using the newest Census data, which would automatically provide better insights into the state of the sectors and emissions through comparing how industries emissions and payroll have changed since 2012, especially with more knowledge of what specific industries and businesses within those sectors have been doing to reduce emissions and energy costs. That type of study may provide clearer results than mine as there would be something to compare to and actual policies to analyze as to how those changes occurred.

Besides these overall conclusions about the state of emissions data, and how this method could be further improved upon in further studies, there were some patterns and insights that I believe do address the question I was seeking to answer. Many of these include answers that have multiple angles or explanations, and because of only using two pieces of data as inputs, payroll and emissions of CO2, being cautious in the conclusions reached is important. Following are attempts to break out some of the patterns seen, and provide possible reasons as it related to the question of how to prioritize decarbonization at the state level.

Some of the more interesting patterns seen in this study came from looking at the side by side comparisons of one sector at a time over all states (Graphs 50-59). When
comparing the states estimated emissions in the Mining sector, states that stuck out as having higher emissions were West Virginia, Wyoming and Kentucky. A reminder that under the NAICS definitions, mining includes: “coal mining, both bituminous coal and lignite surface mining as well as bituminous coal underground mining, anthracite mining, metal ore mining, nonmetallic mineral mining and quarrying. Does not include support activities for mining (these fall under 213).” These three states leading the way match almost identically other emissions data for these states as far as coal mining, which show that Wyoming, West Virginia, Pennsylvania, Illinois and Kentucky led the way in coal production and emissions in 2016. (Administration n.d.) This at least offers some validation of the data used and the results that came from them. It also matches economic data for which states benefit most from mining and seems to match patterns of employment in the mining industry as well. (Energy n.d.)

It’s also a noticeable pattern that no single state profile showed mining as the highest or even close to highest emissions contributor. This could mean that the process of mining may not be as much of a contributor of emissions per dollar to state economies as it is sometimes made out to be in US politics. Although the use of its product (which is what would need to be reduced in other sectors) is still a large contributor, and while not accounted for in this sector, the use of the product impacts all other sectors through energy use. The data as far as how it relates to employment however, does make sense since employment of miners, coal in particular is extremely low across the United States, at less than 50,000 in 2015. (Statistics n.d.) Even for the three highest states on the Mining sectors overall US profile, none had mining in the top three sectors of emissions. This may provide insight into how mining as an industry, may be an area where
decarbonization (probably through fuel switching) is possible without extreme loss to states economies or employment. It is important to note that some states had data withheld from the US Census Bureau’s report on annual payroll to “avoid disclosing data for individual companies”. These states were Delaware, Massachusetts, Nebraska and North Carolina, and so their mining totals were not able to be accounted for and may have (but is doubtful based on the implication that there is only one or two companies within the state) more impact than shown on the graphs.

Of course, accounting for the fact that every lost job as a result of decarbonization is an issue, it is important to acknowledge the results of this paper do not attempt to tackle the issue of where people currently employed in emissions intensive industries will move to, or the effort that it will take to do so fairly and with cooperation. That is another topic that has begun to be discussed at federal policy levels, and could perhaps benefit from understanding what other industries besides coal mining will be facing similar movement of employees if industries decarbonize. This study also does not account for the carbon intensity of coal, which may result in the sector showing lower estimated emissions than it actually contributes. Because of the way the sectors are broken up by NAICS code, the data set has a quirk, in that many of the emissions that would normally be attributed to that sector are exported to other sectors (probably why Manufacturing is the highest out of all sectors for most states).

For Oil and Gas (Graph 52), Texas, Wyoming and Louisiana were the states with highest emissions which also matches well with traditional emissions data as far as biggest oil and gas producing states in the US. (U. E. Administration n.d.) Individual state profiles show that Oil and Gas has a higher contribution at the individual state level
for Wyoming than Texas or Louisiana. This may be attributable to the fact that Wyoming has a smaller population and economy compared to other states, which may result in oil and gas being a larger portion of the pie for emissions and impact on the economy.

Another pattern that sticks out from the results of Oil and Gas is that there is a relatively small number of states that even show this industry as a contributor at all. 17 out of the 50 states have high enough emissions amounts to appear, with the majority of the states not appearing meaning they have no payroll data at all in this category of industry or have had data withheld to protect certain individual companies (North Carolina). This again provides insight that while petroleum and its products may be used further down the supply chain, the economic impacts of its production and extraction are divided between a small number of US states, and within those are not a major contributor of emissions per payroll dollar when estimated as a portion of payroll.

One of the biggest patterns that sticks out in the graphs of all sectors by state is that Texas dominates in all categories. This again matches data from EIA which shows that with 596 million metric tons of CO2 in 2012, Texas had the highest emissions levels as well as one of the highest total annual payroll amounts at $552,624,339,000 out of all states in 2012, behind California ($948,188,503,000). This would explain why the emissions for Texas are the highest in every sector category compared to other states simply due to the difference in scale of the amount of people employed and amount of emissions emitted for their state.

When looking at the results on Manufacturing by states, it is again important to remember the NAICS definition of what is included when talking about manufacturing: “Manufacturing includes the following categories: Food manufacturing, Beverage and

Many of these, such as paper manufacturing, petroleum and coal products manufacturing, chemical manufacturing and textile manufacturing are all very energy intensive processes that lend themselves to high emissions. It also makes sense that so many states would have manufacturing as the highest emissions category since it covers such a wide variety of processes. Out of the 50 states looked at in this study, 38 out of 50 had Manufacturing as the highest category of emissions. This result lends itself to the conclusion that one place where decarbonization efforts may be hardest to achieve as well as most needed, is in the manufacturing sector. How to go about this is trickier, as each of the subcategories within manufacturing have specific energy requirements and emissions contributions that would have to be addressed. “Greening the supply chain” is a topic that continues to be studied and that relates directly to decarbonization of manufacturing. (Greening the Supply Chain: Best Practices and Future Trends 2012) Results from this study show that because of the economic impact of these emissions on states, this may be one industry where emissions reductions will need to be both creative
and thoughtful so as not to reduce economic output for US state economies, especially since a majority of states show that manufacturing is a high contributor of emissions as well as a high portion of the payroll amounts paid out. Another way to consider how to impact the emissions from manufacturing is to aim higher up the supply chain, with a policy that is simple and can address all aspects further down such as a price on carbon.

Transportation and Utilities were both industries that ranked low in emissions both overall across the states in the amount of emissions as well as at the individual state level. Neither was the highest sector of emissions for any state, and both could be examples of industries where decarbonization may be an easier process due to the small amount of emissions when compared against other sectors. These might also be places where jobs in the sector may produce less emissions than their products. Transportation does not include emissions from actual driving in this study, but does include payroll data of: “Air Transportation, Rail Transportation, Water Transportation, Truck transportation, Transit and Ground Passenger Transportation, Pipeline Transportation, Scenic and sightseeing transportation, Support Activities for Transportation, Postal Service, Couriers and Messengers, Warehousing and Storage.” Because the study was unable to account for differences in energy intensity, it may be that the actual emissions from the transportation sector are higher than shown in this study, especially since transportation as described by NAICS does not account for actual combustion emissions. But when looking at emissions via payroll, it remains a relatively small portion for most states. Transportation is one area that has been notoriously hard to decarbonize due in part to our reliance on fossil fuel petroleum as the main source for automobiles and other forms of transport (trains, planes, etc.), but trends in electric vehicle adoption and electrification of public transport
are signs that this may be changing. (International Energy Agency n.d.) The results of this study show that this again may be a sector where states can begin to think about decarbonization with less payroll impact to consider.

Utilities, which includes “…establishments engaged in the provision of the following utility services: electric power, natural gas, steam supply, water supply, and sewage removal. Within this sector, the specific activities associated with the utility services provided vary by utility: electric power includes generation, transmission, and distribution; natural gas includes distribution; steam supply includes provision and/or distribution; water supply includes treatment and distribution; and sewage removal includes collection, treatment, and disposal of waste through sewer systems and sewage treatment facilities.” Is another interesting example of an area that may provide insight into a part of the system where decarbonization efforts could be taken, although interesting to note that the emissions from this sector are not very high. The results shown in this study most likely have changed rapidly since 2012 when this data was collected, as the electrification of systems and the explosion of solar and wind in many states has changed the way utilities operate. (Bade 2015) Power generation, transmission and distribution, once areas dominated by monopoly type utility companies has begun to shift towards distributed energy, with solar and wind taking larger chunks out of what was once a single or small company dominated industry. Based on this 2012 data however, most states emissions of utilities were relatively small, with almost all states below 3,000,000 metric tons. The current changes in 2017, in utility operation as well as changes in generation and distribution may support the observation in this study that the utility industry has changed partially with little economic harm because of the small
impact on emissions by state, as well as the small impact on payroll numbers. Of course, this confirmation would rely on further studies comparing the results of my study from 2012 and future years once the newest Census is completed, but this comparison could provide valuable insight into both the validity of this study as well as the validity of using payroll and emissions to understand potential areas optimal for decarbonization.

One of the other pieces of information that was included in this study was which states were Democratic or Republican governed at the time this data was collected. This can be seen in graphs 50-59, with colored bars representing the respective parties (blue for Democrat and red for Republican). It was interesting to note that 2012 was also a year when political governorships were changing, and fewer states are currently governed by Democrats than in 2012. In this snapshot though, it is interesting to note a few patterns for the sectors investigated. For Oil and Gas, states with high emissions were mostly governed by Republicans (and continue to be) which may explain why it has been difficult to move these states towards decarbonization policies for that specific sector. For Mining, it is interesting to note that 2 of the 3 highest emitting states were governed by Democrats in 2012 (this has since changed to all three being governed by Republicans).

For Construction, 4 out of the 5 top emitting states were governed by Republicans in 2012. The same was true of Retail Trade and Utilities. Transportation was a more even split between Democratic governance and Republican. While it’s hard to make assumptions about why these are the case without diving deep into individual state policies, it also lends to the common understanding that Democratic controlled states tend to be more accepting of decarbonization policies than those governed by Republicans, and can provide insight into why it has been difficult to begin to decarbonize these
sectors at the state level. Many of the Democratically controlled states in all the results per sector show they have some of the lowest emissions levels, which again is backed up by current data showing that states with Democratic control tend to have lower emissions levels. This all lends itself to the discussion of why some sectors and states may have a harder time reducing emissions through decarbonization. Is it because they rely on high emissions industries for economic growth, or because politicians are blocking policies to reduce emissions in the first place? Previous studies looking at why certain states tend to move toward reducing carbon policies also lends itself to the fact that for many Democratic controlled states, they have the resources available (hydro for example) that make this economically easier. (Dietz, et al. 2014) (Ormond 2015) The data from this study seems to back that idea up, with many of the states with lower emissions matching Democratic controlled governorships in 2012.

Other unique observations from the data show that some states stick out as unique in their estimated emissions profiles when using payroll. Florida, Montana, New York, and the District of Columbia for example, are states where Retail Trade was the sector with highest emissions. This is unique, and can be explained for DC, by the fact that it is such a small “state” with no electricity generation, nor high levels of mining or oil and gas or manufacturing facilities in its borders. For Florida, this can also be explained through the high levels of payroll in the retail trade, and for past data showing that Florida had higher retail trade sales than any other state in the US in 2014 (Commentary 2014). Tourism, both domestic and international are contributors to this phenomenon and it lends itself that emissions would also be high in this sector due to continued high level
of retail sales in Florida. The same can be said for New York and possibly Montana, which has low population and low impact of industrial factories in the state.

CONCLUSION

Initially, I hoped to use emissions data and employment data of each of the United States and subsector industries within each state to compare emissions and employment for my study. The hope was to understand how emissions matched up with employment, and which industries in each state were providing jobs as well as contributing the most and least to emissions of carbon dioxide. This turned out to be a much harder feat than initially thought, as there is no data specific enough to make clear conclusions down to industry level as far as emissions go. Data on end use of energy is tracked but only at a high level (Industrial, Residential, etc) and there was no easy way to match up NAICS codes of employment with the emissions data from EPA and EIA. Through this discovery of the lack of data, I devised the procedure used in this paper, using annual payroll and emissions as a way to divide up the “pie” of state emissions by sector, in order to best estimate how emissions were distributed by sector. While this data lacks some insight into energy use of sectors and how intensity differs, I do believe it offers a unique glimpse into how sector emissions can be considered when taking into account the jobs and economic impact those jobs have on state economies.

The data shown in this study offers new insight into how manufacturing may prove to be the hardest and most necessary sector to decarbonize, if the United States is serious about reducing emissions. Finding ways to reduce emissions simply and efficiently, in ways that will hit all of the sectors in the economy rapidly is something that
this paper may be able to help with. In understanding how our energy uses are used down the supply line, we may come up with better ways to regulate them further up the supply chain, in order to maximize our emissions reductions.

Further investigations using this data will hopefully account for energy intensity, comparisons of new data from the US census, as well as investigating how state policies influence the emissions results seen. A comparison study of 2015 data once Census data is available would offer valuable insights into both the accuracy of the data shown here, as well as aid in understanding how processes have changed between 2012 and today. Even better would be to have data tracked on specific industries, businesses and sectors as to the exact emissions being released through energy use and processes, in order to most accurately compare emissions and employment by sectors.

Until data can be accurately captured and studied, the need to investigate new and unique ways to estimate emission by sector is useful. Through the work of this paper, and future studies into tracking and reporting of emissions, there can be greater understanding of our future of decarbonization, and a rapid uptake of policies that are both beneficial to the environment as well as our state and federal economy.
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