Project 4 – Stat 133

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Effective Energy Transitions

Introduction:

The push for a nationwide clean energy transition is largely driven by state policies, creating a patchwork of progress across the United States. This is because federal agencies set broad standards, and states retain significant control over their energy generation mix and resource planning. This decentralized authority means that some states are aggressively pursuing 100% clean energy goals, while others are much slower for various reasons. The transition to renewables is crucial not only for mitigating the global climate crisis and improving public health but also for enhancing local energy security, creating new jobs, and insulating consumers from the volatility of global fossil fuel markets. We should ask the critical question: Which states are doing a better job transitioning to renewable energy sources?

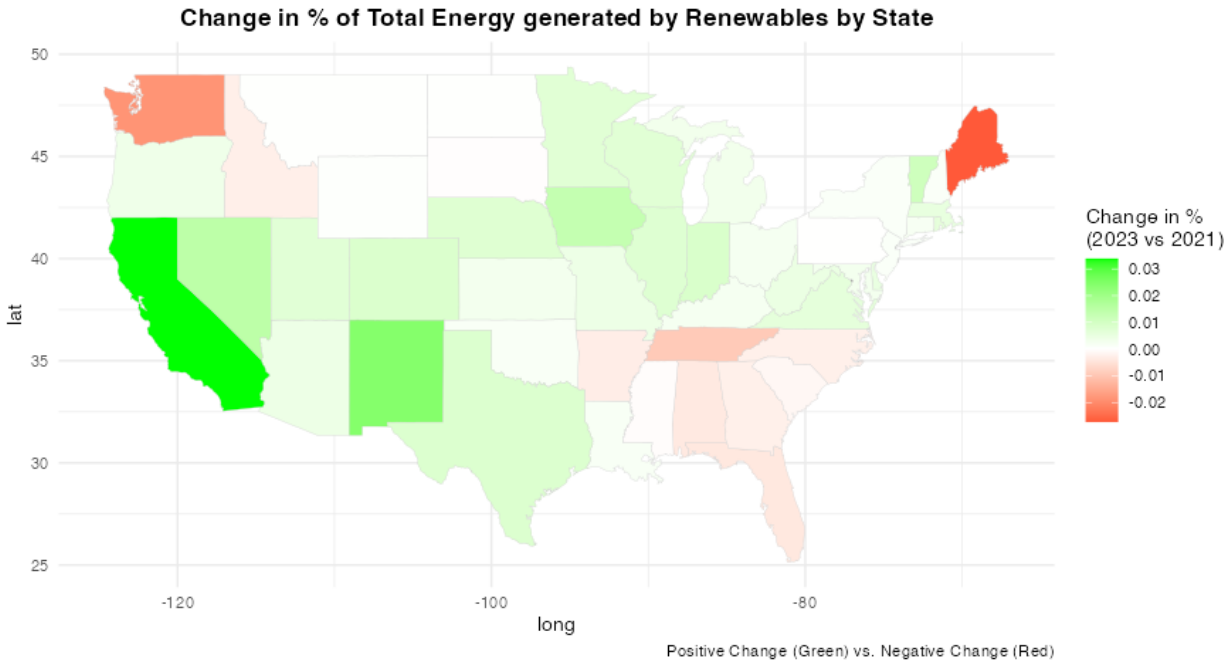
Data/Methods:

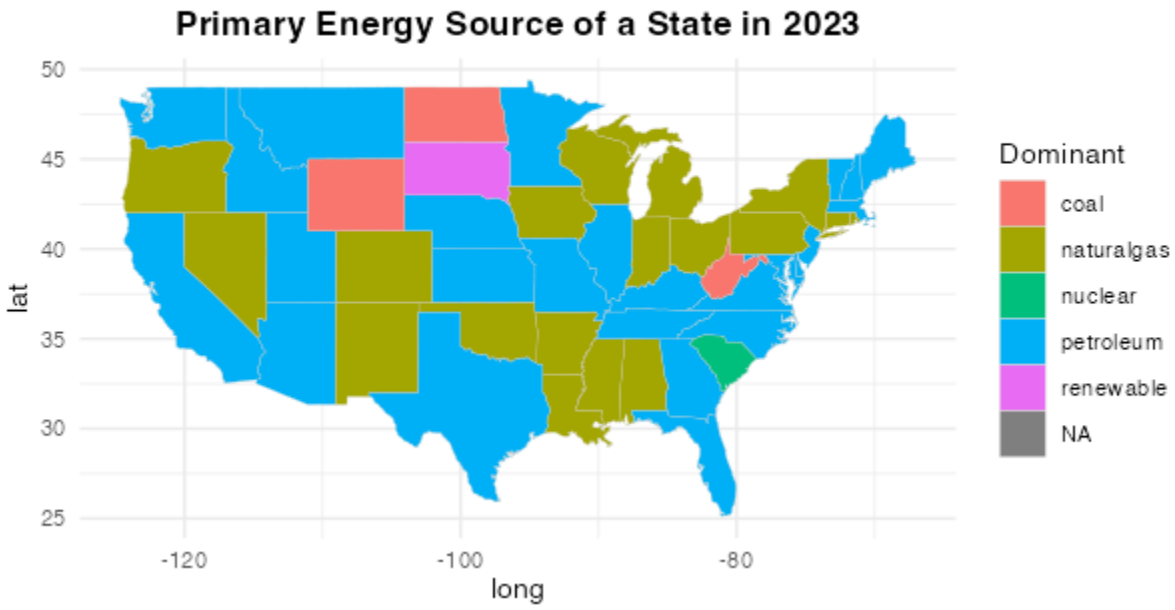
3 data sets were used, each similar showing the amount of energy derived from coal, natural gas, petroleum, nuclear, and renewable sources. After cleaning they look like this

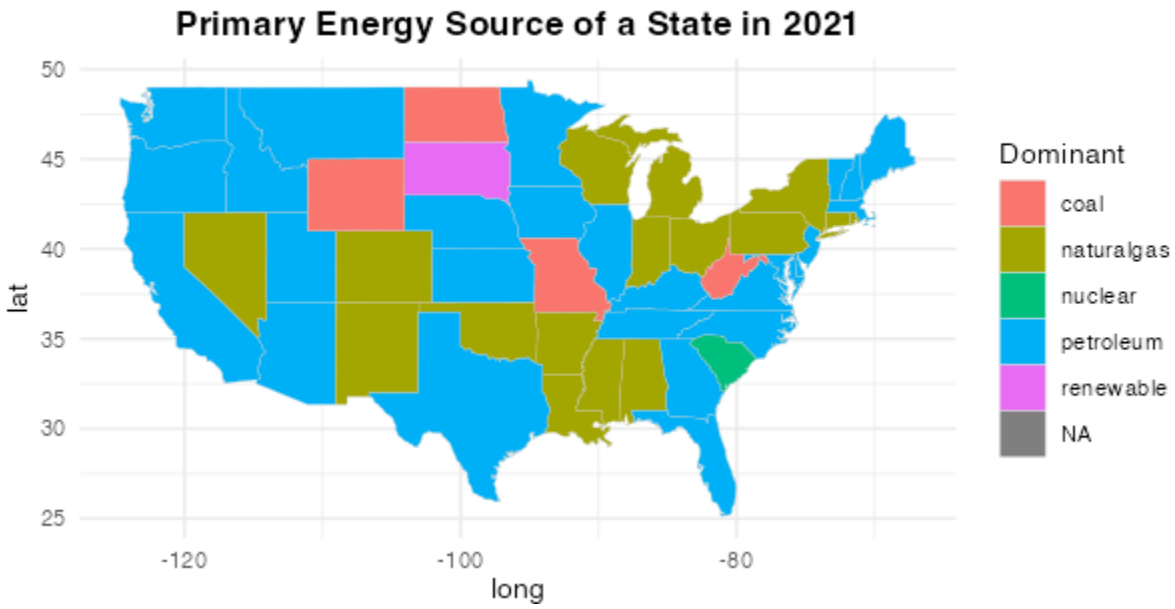
```
# A tibble: 6 × 8
  State   coal naturalgas petroleum nuclear renewable   total `2021`
  <chr>  <dbl>      <dbl>     <dbl>   <dbl>     <dbl>   <dbl>  <dbl>
1 AK     18694     395590    261094       0      9597  684975 0.0140
2 AL    309791     739891    583042  480115    239817 2352656 0.102
3 AR    216123     360545    328271  141372     89714 1136025 0.0790
4 AZ    160299     484962    606862  329868     99266 1681257 0.0590
5 CA     28244    2172757   2959389  171842    810020 6142252 0.132
6 CO    252442     509970    497788       0    103955 1364155 0.0762
# A tibble: 6 × 8
  State   coal naturalgas petroleum nuclear renewable   total `2022`
  <chr>  <dbl>      <dbl>     <dbl>   <dbl>     <dbl>   <dbl>  <dbl>
1 AK     18615     437916    263335       0     10410  730276 0.0143
2 AL    297654     787300    578431  442093    232035 2337513 0.0993
3 AR    211724     398099    327813  149654     90825 1178115 0.0771
4 AZ    154007     468038    594859  333738    101215 1651857 0.0613
5 CA     30049    2131372   3017944  183814    880995 6244174 0.141
6 CO    233256     524890    538413       0    114917 1411476 0.0814
# A tibble: 6 × 8
  State   coal naturalgas petroleum nuclear renewable   total `2023`
  <chr>  <dbl>      <dbl>     <dbl>   <dbl>     <dbl>   <dbl>  <dbl>
1 AK     18414     448087    270391       0     10087  746979 0.0135
2 AL    224926     775747    565754  476392    222189 2265008 0.0981
3 AR    180262     399566    327465  156492     87277 1151062 0.0758
4 AZ    137885     537151    599712  329474    108445 1712667 0.0633
5 CA     28746    2154533   2996168  185192   1065179 6429818 0.166
6 CO    204826     525446    514174       0    115061 1359507 0.0846
```

These datasets were combined and merged with geospatial data from the maps library to generate these maps

Map Visualization:







Three choropleth maps were generated using the ggplot2 package:

Map 1 – Percent Change in Renewable Energy (2021–2023):

This map displayed each state shaded by the percentage change in renewable energy share. States with higher increases appeared in darker green tones, indicating rapid progress toward clean energy generation.

Map 2 – Dominant Energy Source in 2021:

Each state was colored according to its primary energy source in 2021. Most of the Southeast and Midwest showed dominance of coal, while the West and Northeast exhibited higher shares of renewables or natural gas.

Map 3 – Dominant Energy Source in 2023:

Similar to Map 2, but based on 2023 data. Several states transitioned from coal or natural gas dominance to renewables, particularly in the Midwest and parts of the Southwest, highlighting ongoing structural changes in state energy portfolios.

These maps were created with:

```
ggplot(data = merged_data) +
  geom_polygon(aes(x = long, y = lat, group = group, fill = variable), color = "white") +
  coord_fixed(1.3) +
  theme_minimal()
```

Analysis/Conclusions:

The maps reveal several clear trends. First, renewable energy usage increased across most almost all states from 2021 to 2023, though the rate of change was uneven. States such as California, New York, and Colorado showed significant growth in renewable shares, while states in the Southeast tend to be slower, sometimes regressive.

The dominant energy source maps show how the use of coal as declined, and in a few states has been removed in favor of natural gas. In 2021, coal dominated much of the central U.S., but by 2023, many of these same states had shifted toward natural gas or renewables. This pattern suggests that cleaner fuels are gradually replacing coal, though fossil fuels still underpin much of the national grid and that cleaner fuels are a “next best option” given the wide spread opposition to full renewable transitions.

The map comparison also highlights regional policy effects: states with ambitious renewable portfolio standards or strong public investment (e.g., California, New Mexico, Maine) have advanced faster than those relying primarily on legacy fossil fuel infrastructure. Most states demonstrated measurable increases in renewable energy generation between 2021 and 2023, though the pace varies widely.

These findings support the idea that state-level policy leadership—not federal mandates alone—drives clean energy progress. States that invested early in wind and solar infrastructure or adopted aggressive carbon reduction targets now lead the transition, while those without comparable policy frameworks trail behind.

Further research could integrate additional years of data to assess long-term consistency, explore the influence of federal incentives such as the Inflation Reduction Act, and link these patterns to emissions outcomes and economic indicators such as energy employment growth. It could also explore which energy sources states are transitioning to after moving away from more harmful sources (ie from coal to nuclear or from coal to nature gas)