EV Power - Lab 4 Project Report

Example Solution 1

Part 0: libraries

```
library(tidyverse)
```

```
── Attaching core tidyverse packages ──────────────────────── tidyverse 2.0.0
──
✔ dplyr     1.1.4     ✔ readr     2.1.5
✔ forcats   1.0.1     ✔ stringr   1.5.2
✔ ggplot2   4.0.0     ✔ tibble    3.3.0
✔ lubridate 1.9.4     ✔ tidyr     1.3.1
✔ purrr     1.1.0
── Conflicts ────────────────────────────────────────── tidyverse_conflicts()
──
✖ dplyr::filter() masks stats::filter()
✖ dplyr::lag()    masks stats::lag()
ℹ Use the conflicted package (<http://conflicted.r-lib.org/>) to force all
conflicts to become errors
```

```
library(stringr)
library(dplyr)
```

Part 1: Defining Research Question

Chosen Question: How does the proportion of renewable energy vary geographically across the United States? Does a relationship exist between renewable energy share and electricity pricing by state?

Part 2: Data Preparation and Cleaning

```
# Check current working directory
getwd()
```

```
[1] "C:/Users/garva/Documents/Code Projects/ev-power-garv-agarwal"
```

```r
# View available files
list.files()
```

```
[1] "data"             "ev-dashboard.qmd" "project.qmd"
"README.md"
[5] "report.qmd"       "report.rmarkdown" "worksheet.qmd"
```

```r
# Set working directory to data folder
setwd("C:/Users/garva/Documents/Code Projects/ev-power-garv-agarwal/data")

# Import renewable energy usage data (2021-2023)
renewable_21 <- read.csv("renew-use-2021.csv")
renewable_22 <- read.csv("renew-use-2022.csv")
renewable_23 <- read.csv("renew-use-2023.csv")

# Import total energy consumption data (2021-2023)
total_21 <- read.csv("total-use-2021.csv")
total_22 <- read.csv("total-use-2022.csv")
total_23 <- read.csv("total-use-2023.csv")

# Import pricing and registration data
energy_prices <- read.csv("av-energy-price-2021-2023.csv", header = FALSE)
ev_data <- read.csv("ev-registrations-by-state-2023.csv")

## Examine dataset structures
str(renewable_21)
```

```
'data.frame':   260 obs. of  3 variables:
 $ State             : chr  "AK" "AK" "AK" "AK" ...
 $ Energy_Source     : chr  "Biomass" "Geothermal" "Hydropower" "Solar
Energy" ...
 $ Renewable_Use_2021: chr  "≈3153" "186 MMBtu" "5763 about" "~45" ...
```

```r
str(renewable_22)
```

```
'data.frame':   260 obs. of  3 variables:
 $ State             : chr  "AK" "AK" "AK" "AK" ...
 $ Energy_Source     : chr  "Biomass" "Geothermal" "Hydropower" "Solar
Energy" ...
 $ Renewable_Use_2022: chr  "≈3846" "$186" "$5846" "~57" ...
```

```r
str(renewable_23)
```

```
'data.frame':   260 obs. of  3 variables:
 $ State             : chr  "AK" "AK" "AK" "AK" ...
 $ Energy_Source     : chr  "Biomass" "Geothermal" "Hydropower" "Solar
Energy" ...
 $ Renewable_Use_2023: chr  "3404 kWh" "186.0" "6051" "67" ...
```

```
head(renewable_21)
```

```
  State Energy_Source Renewable_Use_2021
1    AK       Biomass              ≈3153
2    AK    Geothermal          186 MMBtu
3    AK    Hydropower         5763 about
4    AK  Solar Energy               ~45
5    AK   Wind Energy            451 USD
6    AL       Biomass        198543 est.
```

```
head(renewable_22)
```

```
  State Energy_Source Renewable_Use_2022
1    AK       Biomass              ≈3846
2    AK    Geothermal               $186
3    AK    Hydropower              $5846
4    AK  Solar Energy               ~57
5    AK   Wind Energy               $475
6    AL       Biomass         193932 USD
```

```
head(renewable_23)
```

```
  State Energy_Source Renewable_Use_2023
1    AK       Biomass           3404 kWh
2    AK    Geothermal              186.0
3    AK    Hydropower               6051
4    AK  Solar Energy                 67
5    AK   Wind Energy                380
6    AL       Biomass         189040 kWh
```

```
str(total_21)
```

```
'data.frame':   5 obs. of  53 variables:
 $ Energy_Source: chr  "Coal" "Natural Gas†" "Petroleum (BTU)" "nuclear" ...
 $ AK           : int  18694 395590 261094 0 9597
```

```
$ AL          : int  309791 739891 583042 480115 239817
$ AR          : int  216123 360545 328271 141372 89714
$ AZ          : int  160299 484962 606862 329868 99266
$ CA          : int  28244 2172757 2959389 171842 810020
$ CO          : int  252442 509970 497788 0 103955
$ CT          : int  2880 305184 284788 179551 49306
$ DC          : int  0 28336 18439 0 2487
$ DE          : int  4542 82708 113641 0 7150
$ FL          : int  200193 1591864 1748346 307811 297291
$ GA          : int  203870 773889 922503 354085 289113
$ HI          : int  12566 133 223014 0 20134
$ IA          : int  264419 383424 408385 0 389787
$ ID          : int  3051 135176 188263 0 74428
$ IL          : int  522809 1088485 1136797 1011555 224106
$ IN          : int  753557 869328 712427 0 157324
$ KS          : int  219031 291797 339006 89426 135551
$ KY          : int  548443 365875 584011 0 71744
$ LA          : int  95856 1862349 1840835 179886 135905
$ MA          : int  0 404301 503312 0 75370
$ MD          : int  69186 299282 433791 156369 52732
$ ME          : int  1588 57233 163991 0 95141
$ MI          : int  436203 950364 814081 358114 194075
$ MN          : int  179055 523812 561731 147286 216113
$ MO          : int  616413 293633 607276 44766 88879
$ MS          : int  64446 576903 384328 122771 66134
$ MT          : int  122765 87105 176686 0 56334
$ NC          : int  222501 637553 884299 449675 196973
$ ND          : int  361811 191168 168682 0 92653
$ NE          : int  216298 191008 237214 71758 158275
$ NH          : int  3259 60116 142030 102789 38479
$ NJ          : int  12586 697019 749892 293494 70039
$ NM          : int  133228 285809 262885 0 62210
$ NV          : int  35910 305212 286548 0 63647
$ NY          : int  5370 1359437 1237451 325141 263977
$ OH          : int  575920 1294814 1028000 182330 146858
$ OK          : int  131695 745911 517408 0 177087
$ OR          : int  1303 305665 317322 0 225544
$ PA          : int  485193 1868137 1047658 791587 179589
$ RI          : int  0 105473 76464 0 11798
$ SC          : int  162628 349990 508147 560782 143796
$ SD          : int  21589 96787 119505 0 127382
$ TN          : int  225784 413554 713210 368461 135841
$ TX          : int  968401 4773076 6783182 419363 654199
$ UT          : int  276159 274420 304823 0 36050
$ VA          : int  68603 699927 795296 297972 174615
$ VT          : int  0 13801 72241 0 21430
$ WA          : int  36943 384769 711662 88764 394052
$ WI          : int  286760 561076 533390 103979 145936
```

```
 $ WV           : int  633582 277002 205005 0 26427
 $ WY           : int  376971 161580 146274 0 37734
 $ US           : int  10548957 31688203 35250685 8130913 7646167
```

```
str(total_22)
```

```
'data.frame':   5 obs. of  53 variables:
 $ Energy_Source: chr  "coal Consumption" "Natural-Gas" "petroleum (btu)"
"Nuclear Energy†" ...
 $ AK           : int  18615 437916 263335 0 10410
 $ AL           : int  297654 787300 578431 442093 232035
 $ AR           : int  211724 398099 327813 149654 90825
 $ AZ           : int  154007 468038 594859 333738 101215
 $ CA           : int  30049 2131372 3017944 183814 880995
 $ CO           : int  233256 524890 538413 0 114917
 $ CT           : int  0 307212 302881 172018 49084
 $ DC           : int  0 30174 18000 0 2622
 $ DE           : int  1846 89674 112026 0 7402
 $ FL           : int  171953 1659544 1815529 321468 304605
 $ GA           : int  180888 809618 940579 356001 293237
 $ HI           : int  7680 159 241994 0 20471
 $ IA           : int  227866 434374 423592 0 421784
 $ ID           : int  1881 141924 190635 0 78406
 $ IL           : int  496983 1134781 1138141 1032989 248541
 $ IN           : int  719238 913401 699235 0 170986
 $ KS           : int  226712 318779 346852 93844 151788
 $ KY           : int  523276 402534 580349 0 77517
 $ LA           : int  96914 2087166 1663129 168889 138209
 $ MA           : int  0 432442 529154 0 80700
 $ MD           : int  61932 310133 411842 154742 51255
 $ ME           : int  1269 62559 166724 0 93867
 $ MI           : int  423504 1087716 820709 271788 206811
 $ MN           : int  184517 535010 568916 153546 229769
 $ MO           : int  566940 322547 606374 92724 95312
 $ MS           : int  66214 617855 383366 89856 66614
 $ MT           : int  131345 93971 177009 0 60644
 $ NC           : int  163029 747187 906477 445547 198165
 $ ND           : int  369340 198986 170390 0 96024
 $ NE           : int  223571 199260 237556 58702 168382
 $ NH           : int  3864 60176 149025 114108 39863
 $ NJ           : int  6199 755048 769751 295875 73187
 $ NM           : int  138077 301279 255571 0 77286
 $ NV           : int  35835 302315 303234 0 72734
 $ NY           : int  6143 1403401 1321362 280133 269884
 $ OH           : int  539587 1422175 1031807 175806 155282
 $ OK           : int  106855 772405 521629 0 189654
```

```
 $ OR           : int  1066 297591 315400 0 237768
 $ PA           : int  435540 1936985 1108074 795783 182051
 $ RI           : int  0 93829 78260 0 13264
 $ SC           : int  150973 361249 495616 568055 145328
 $ SD           : int  24769 98288 118593 0 129978
 $ TN           : int  204725 440017 707095 372319 116472
 $ TX           : int  932569 5007366 6582173 434709 751680
 $ UT           : int  237870 287076 322387 0 37369
 $ VA           : int  67739 665869 798162 294606 185638
 $ VT           : int  0 14046 71534 0 22009
 $ WA           : int  42238 381886 725931 102929 418470
 $ WI           : int  232501 622144 535483 105285 150890
 $ WV           : int  536642 281657 201769 0 28391
 $ WY           : int  390303 172450 145723 0 42079
 $ US           : int  9885694 33361871 35330835 8061020 8107353
```

```
str(total_23)
```

```
'data.frame':   5 obs. of  53 variables:
 $ Energy_Source: chr  "coal_usage" "NaturalGas" "petroleum (BTU)" "nuclear-
energy †" ...
 $ AK           : int  18414 448087 270391 0 10087
 $ AL           : int  224926 775747 565754 476392 222189
 $ AR           : int  180262 399566 327465 156492 87277
 $ AZ           : int  137885 537151 599712 329474 108445
 $ CA           : int  28746 2154533 2996168 185192 1065179
 $ CO           : int  204826 525446 514174 0 115061
 $ CT           : int  0 304924 292864 142873 48981
 $ DC           : int  0 26236 17292 0 2795
 $ DE           : int  338 84387 110721 0 8041
 $ FL           : int  129387 1673836 1835394 312935 286306
 $ GA           : int  177521 787361 980546 390663 291462
 $ HI           : int  0 152 251676 0 21046
 $ IA           : int  201276 446677 404172 0 414801
 $ ID           : int  1144 154150 189553 0 77128
 $ IL           : int  342683 1101064 1134461 1019691 245703
 $ IN           : int  613533 921814 695709 0 172891
 $ KS           : int  184614 309427 345807 107675 140268
 $ KY           : int  481815 369986 584722 0 72603
 $ LA           : int  58224 2055504 1620038 127634 138982
 $ MA           : int  0 386946 525647 0 81559
 $ MD           : int  30349 304669 429784 156610 53711
 $ ME           : int  1295 61045 177091 0 89444
 $ MI           : int  287490 1104234 810789 292615 198459
 $ MN           : int  148968 536789 567072 124626 223864
 $ MO           : int  442901 316512 612625 95947 90412
```

```
 $ MS           : int  49606 630107 378072 122807 67305
 $ MT           : int  130059 96777 173283 0 58470
 $ NC           : int  153784 662302 900241 442493 186804
 $ ND           : int  325716 220768 169307 0 92154
 $ NE           : int  195602 206276 233599 72391 164502
 $ NH           : int  1838 59589 147387 99658 38988
 $ NJ           : int  0 721282 787262 296162 74408
 $ NM           : int  75182 337083 251686 0 80278
 $ NV           : int  29284 301655 296155 0 74878
 $ NY           : int  4823 1346622 1341811 287690 272967
 $ OH           : int  413577 1448857 1009729 169392 153083
 $ OK           : int  63787 860217 515440 0 185378
 $ OR           : int  652 327164 313013 0 236062
 $ PA           : int  307604 1937041 1132958 787083 178035
 $ RI           : int  0 112499 76844 0 13579
 $ SC           : int  162323 346881 507146 581365 142486
 $ SD           : int  22246 99752 114623 0 126540
 $ TN           : int  202367 396870 702827 396522 115678
 $ TX           : int  805600 5284670 6752349 425186 791211
 $ UT           : int  174315 298976 324640 0 39674
 $ VA           : int  46785 655997 807547 310037 183979
 $ VT           : int  0 13001 70235 0 22209
 $ WA           : int  49523 403038 718277 88163 365956
 $ WI           : int  219995 565025 525386 101204 150965
 $ WV           : int  472309 309019 206969 0 28370
 $ WY           : int  366098 181395 143944 0 38474
 $ US           : int  8169673 33609104 35460356 8098974 8187317
```

```
head(total_21)  # Will need to reshape these dataframes
```

```
           Energy_Source     AK     AL     AR     AZ      CA     CO     CT
1                  Coal  18694 309791 216123 160299   28244 252442   2880
2           Natural Gas† 395590 739891 360545 484962 2172757 509970 305184
3        Petroleum (BTU) 261094 583042 328271 606862 2959389 497788 284788
4                nuclear      0 480115 141372 329868  171842      0 179551
5 total_renewable_energy   9597 239817  89714  99266  810020 103955  49306
     DC     DE      FL     GA     HI     IA     ID      IL     IN     KS
KY
1     0   4542  200193 203870  12566 264419   3051  522809 753557 219031
548443
2 28336  82708 1591864 773889    133 383424 135176 1088485 869328 291797
365875
3 18439 113641 1748346 922503 223014 408385 188263 1136797 712427 339006
584011
4     0      0  307811 354085      0      0      0 1011555      0  89426
0
```

```
5  2487   7150  297291 289113  20134 389787  74428  224106 157324 135551
71744
       LA     MA     MD     ME     MI     MN     MO     MS     MT     NC
ND
1   95856      0  69186   1588 436203 179055 616413  64446 122765 222501
361811
2 1862349 404301 299282  57233 950364 523812 293633 576903  87105 637553
191168
3 1840835 503312 433791 163991 814081 561731 607276 384328 176686 884299
168682
4  179886      0 156369      0 358114 147286  44766 122771      0 449675
0
5  135905  75370  52732  95141 194075 216113  88879  66134  56334 196973
92653
      NE     NH     NJ     NM     NV      NY      OH     OK     OR      PA
1 216298   3259  12586 133228  35910    5370  575920 131695   1303  485193
2 191008  60116 697019 285809 305212 1359437 1294814 745911 305665 1868137
3 237214 142030 749892 262885 286548 1237451 1028000 517408 317322 1047658
4  71758 102789 293494      0      0  325141  182330      0      0  791587
5 158275  38479  70039  62210  63647  263977  146858 177087 225544  179589
      RI     SC     SD     TN      TX     UT     VA    VT     WA     WI     WV
1      0 162628  21589 225784  968401 276159  68603     0  36943 286760 633582
2 105473 349990  96787 413554 4773076 274420 699927 13801 384769 561076 277002
3  76464 508147 119505 713210 6783182 304823 795296 72241 711662 533390 205005
4      0 560782      0 368461  419363      0 297972     0  88764 103979      0
5  11798 143796 127382 135841  654199  36050 174615 21430 394052 145936  26427
      WY       US
1 376971 10548957
2 161580 31688203
3 146274 35250685
4      0  8130913
5  37734  7646167
```

```
head(total_22)  # Will need to reshape these dataframes
```

```
     Energy_Source     AK     AL     AR     AZ      CA     CO     CT    DC
1 coal Consumption  18615 297654 211724 154007   30049 233256      0     0
2      Natural-Gas 437916 787300 398099 468038 2131372 524890 307212 30174
3  petroleum (btu) 263335 578431 327813 594859 3017944 538413 302881 18000
4  Nuclear Energy†      0 442093 149654 333738  183814      0 172018     0
5 total_renewables  10410 232035  90825 101215  880995 114917  49084  2622
      DE      FL     GA     HI     IA     ID      IL     IN     KS     KY
1   1846  171953 180888   7680 227866   1881  496983 719238 226712 523276
2  89674 1659544 809618    159 434374 141924 1134781 913401 318779 402534
3 112026 1815529 940579 241994 423592 190635 1138141 699235 346852 580349
4      0  321468 356001      0      0      0 1032989      0  93844      0
```

```
5   7402  304605 293237  20471 421784  78406  248541 170986 151788  77517
       LA     MA     MD     ME      MI     MN     MO     MS     MT     NC
1   96914      0  61932   1269  423504 184517 566940  66214 131345 163029
2 2087166 432442 310133  62559 1087716 535010 322547 617855  93971 747187
3 1663129 529154 411842 166724  820709 568916 606374 383366 177009 906477
4  168889      0 154742      0  271788 153546  92724  89856      0 445547
5  138209  80700  51255  93867  206811 229769  95312  66614  60644 198165
      ND     NE     NH     NJ     NM     NV      NY      OH     OK     OR
1 369340 223571   3864   6199 138077  35835    6143  539587 106855   1066
2 198986 199260  60176 755048 301279 302315 1403401 1422175 772405 297591
3 170390 237556 149025 769751 255571 303234 1321362 1031807 521629 315400
4      0  58702 114108 295875      0      0  280133  175806      0      0
5  96024 168382  39863  73187  77286  72734  269884  155282 189654 237768
       PA    RI     SC     SD     TN      TX     UT     VA    VT     WA     WI
1  435540     0 150973  24769 204725  932569 237870  67739     0  42238 232501
2 1936985 93829 361249  98288 440017 5007366 287076 665869 14046 381886 622144
3 1108074 78260 495616 118593 707095 6582173 322387 798162 71534 725931 535483
4  795783     0 568055      0 372319  434709      0 294606     0 102929 105285
5  182051 13264 145328 129978 116472  751680  37369 185638 22009 418470 150890
      WV     WY       US
1 536642 390303  9885694
2 281657 172450 33361871
3 201769 145723 35330835
4      0      0  8061020
5  28391  42079  8107353
```

```
head(total_23)  # Will need to reshape these dataframes
```

```
           Energy_Source     AK     AL     AR     AZ      CA     CO     CT
1             coal_usage  18414 224926 180262 137885   28746 204826      0
2             NaturalGas 448087 775747 399566 537151 2154533 525446 304924
3        petroleum (BTU) 270391 565754 327465 599712 2996168 514174 292864
4       nuclear-energy †      0 476392 156492 329474  185192      0 142873
5 total renewable-energy  10087 222189  87277 108445 1065179 115061  48981
     DC     DE      FL     GA     HI     IA     ID      IL     IN     KS
KY
1     0    338  129387 177521      0 201276   1144  342683 613533 184614
481815
2 26236  84387 1673836 787361    152 446677 154150 1101064 921814 309427
369986
3 17292 110721 1835394 980546 251676 404172 189553 1134461 695709 345807
584722
4     0      0  312935 390663      0      0      0 1019691      0 107675
0
5  2795   8041  286306 291462  21046 414801  77128  245703 172891 140268
72603
```

```
       LA     MA     MD     ME      MI     MN     MO     MS     MT     NC
1   58224      0  30349   1295  287490 148968 442901  49606 130059 153784
2 2055504 386946 304669  61045 1104234 536789 316512 630107  96777 662302
3 1620038 525647 429784 177091  810789 567072 612625 378072 173283 900241
4  127634      0 156610      0  292615 124626  95947 122807      0 442493
5  138982  81559  53711  89444  198459 223864  90412  67305  58470 186804
      ND     NE     NH     NJ     NM     NV      NY      OH     OK     OR
1 325716 195602   1838      0  75182  29284    4823  413577  63787    652
2 220768 206276  59589 721282 337083 301655 1346622 1448857 860217 327164
3 169307 233599 147387 787262 251686 296155 1341811 1009729 515440 313013
4      0  72391  99658 296162      0      0  287690  169392      0      0
5  92154 164502  38988  74408  80278  74878  272967  153083 185378 236062
       PA     RI     SC     SD     TN      TX     UT     VA    VT     WA
WI
1  307604      0 162323  22246 202367  805600 174315  46785     0  49523
219995
2 1937041 112499 346881  99752 396870 5284670 298976 655997 13001 403038
565025
3 1132958  76844 507146 114623 702827 6752349 324640 807547 70235 718277
525386
4  787083      0 581365      0 396522  425186      0 310037     0  88163
101204
5  178035  13579 142486 126540 115678  791211  39674 183979 22209 365956
150965
      WV     WY       US
1 472309 366098  8169673
2 309019 181395 33609104
3 206969 143944 35460356
4      0      0  8098974
5  28370  38474  8187317
```

```
str(ev_data)
```

```
'data.frame':   54 obs. of  2 variables:
 $ electric.vehicle.registrations_by_state..2023.: chr  "" "STATE" "Alabama"
"Alaska" ...
 $ X                                             : chr  "" "Count-EVs "
"#13047" "~2697" ...
```

```
head(ev_data)
```

```
  electric.vehicle.registrations_by_state..2023.          X
1
2                                          STATE Count-EVs
```

```
3                                       Alabama     #13047
4                                        Alaska      ~2697
5                                       Arizona      89798
6                                      Arkansas   7108 EVs
```

```
str(energy_prices)
```

```
'data.frame':   55 obs. of  1 variable:
 $ V1: chr  "Total energy average price, dollars per million Btu,,," ",,,"
"State,2021,2022,2023" "AK,$20.03 per MMBtu,$27.33,$23.84 est." ...
```

```
head(energy_prices)
```

```
                                                    V1
1 Total energy average price, dollars per million Btu,,,
2                                                  ,,,
3                                State,2021,2022,2023
4               AK,$20.03 per MMBtu,$27.33,$23.84 est.
5                  AL,about 17.85 USD,23.37 USD,≈21.11
6                    AR,$18.42,$23.84 per MMBtu,$21.76
```

```
## Data cleaning process

## Clean renewable energy datasets
# Extract numeric values from 2021 renewable usage column
renewable_21_clean <- renewable_21 %>%
  mutate(renew_21 = str_extract(Renewable_Use_2021, "\\d+"))

# Apply same extraction for 2022 and 2023
renewable_22_clean <- renewable_22 %>%
  mutate(renew_22 = str_extract(Renewable_Use_2022, "\\d+"))

renewable_23_clean <- renewable_23 %>%
  mutate(renew_23 = str_extract(Renewable_Use_2023, "\\d+"),
         State = str_to_upper(State))

renewable_23_clean
```

```
    State Energy_Source Renewable_Use_2023 renew_23
1      AK       Biomass           3404 kWh     3404
2      AK    Geothermal              186.0      186
3      AK    Hydropower               6051     6051
4      AK  Solar Energy                 67       67
```

```
5      AK   Wind Energy               380      380
6      AL       Biomass         189040 kWh   189040
7      AL    Geothermal             141.0      141
8      AL    Hydropower             28762    28762
9      AL  Solar Energy              4246     4246
10     AL   Wind Energy                0        0
11     AR       Biomass             71311    71311
12     AR    Geothermal           808 MWh      808
13     AR    Hydropower             11017    11017
14     AR  Solar Energy              4141     4141
15     AR   Wind Energy                0        0
16     AZ       Biomass             36572    36572
17     AZ    Geothermal               345      345
18     AZ    Hydropower             20258    20258
19     AZ  Solar Energy             45356    45356
20     AZ   Wind Energy              5914     5914
21     CA       Biomass            612607   612607
22     CA    Geothermal             40578    40578
23     CA    Hydropower            110485   110485
24     CA  Solar Energy            253676   253676
25     CA   Wind Energy             47833    47833
26     CO       Biomass             35513    35513
27     CO    Geothermal               759      759
28     CO    Hydropower          5447 MWh     5447
29     CO  Solar Energy             18440    18440
30     CO   Wind Energy             54903    54903
31     CT       Biomass             40711    40711
32     CT    Geothermal              21.0       21
33     CT    Hydropower              1588     1588
34     CT  Solar Energy              6629     6629
35     CT   Wind Energy                34       34
36     DC       Biomass              1984     1984
37     DC    Geothermal                22       22
38     DC    Hydropower                 0        0
39     DC  Solar Energy               790      790
40     DC   Wind Energy                 0        0
41     DE       Biomass              6383     6383
42     DE    Geothermal               430      430
43     DE    Hydropower                 0        0
44     DE  Solar Energy              1213     1213
45     DE   Wind Energy                14       14
46     FL       Biomass            187267   187267
47     FL    Geothermal             10056    10056
48     FL    Hydropower               765      765
49     FL  Solar Energy             88219    88219
50     FL   Wind Energy                 0        0
51     GA       Biomass            253485   253485
52     GA    Geothermal               315      315
```

```
53     GA    Hydropower              9799     9799
54     GA  Solar Energy             27863    27863
55     GA   Wind Energy                 0        0
56     HI       Biomass              8914     8914
57     HI    Geothermal               665      665
58     HI    Hydropower               318      318
59     HI  Solar Energy              8985     8985
60     HI   Wind Energy              2164     2164
61     IA       Biomass         265747 kWh   265747
62     IA    Geothermal              1281     1281
63     IA    Hydropower              3235     3235
64     IA  Solar Energy              3146     3146
65     IA   Wind Energy            141392   141392
66     ID       Biomass             35074    35074
67     ID    Geothermal              1804     1804
68     ID    Hydropower             28585    28585
69     ID  Solar Energy              3749     3749
70     ID   Wind Energy              7915     7915
71     IL       Biomass            155910   155910
72     IL    Geothermal              2042     2042
73     IL    Hydropower               314      314
74     IL  Solar Energy             13028    13028
75     IL   Wind Energy             74409    74409
76     IN       Biomass            128816   128816
77     IN    Geothermal              4647     4647
78     IN    Hydropower              1582     1582
79     IN  Solar Energy              7669     7669
80     IN   Wind Energy             30177    30177
81     KS       Biomass             45449    45449
82     KS    Geothermal               974      974
83     KS    Hydropower                46       46
84     KS  Solar Energy               745      745
85     KS   Wind Energy             93054    93054
86     KY       Biomass             55351    55351
87     KY    Geothermal              2712     2712
88     KY    Hydropower             13493    13493
89     KY  Solar Energy              1047     1047
90     KY   Wind Energy                 0        0
91     LA       Biomass            132613   132613
92     LA    Geothermal              1842     1842
93     LA    Hydropower              2414     2414
94     LA  Solar Energy              2113     2113
95     LA   Wind Energy                 0        0
96     MA       Biomass             56272    56272
97     MA    Geothermal               859      859
98     MA    Hydropower              3976     3976
99     MA  Solar Energy             19833    19833
100    MA   Wind Energy               620      620
```

```
101    MD       Biomass              37140    37140
102    MD    Geothermal                570      570
103    MD    Hydropower               6309     6309
104    MD  Solar Energy               8049     8049
105    MD   Wind Energy               1643     1643
106    ME       Biomass              64238    64238
107    ME    Geothermal                 72       72
108    ME    Hydropower               13074    13074
109    ME  Solar Energy               4080     4080
110    ME   Wind Energy               7980     7980
111    MI       Biomass             154360   154360
112    MI    Geothermal                5193     5193
113    MI    Hydropower                4760     4760
114    MI  Solar Energy                5851     5851
115    MI   Wind Energy               28294    28294
116    MN       Biomass             162640   162640
117    MN    Geothermal                1075     1075
118    MN    Hydropower                2560     2560
119    MN  Solar Energy                8462     8462
120    MN   Wind Energy               49127    49127
121    MO       Biomass              61275    61275
122    MO    Geothermal                 352      352
123    MO    Hydropower                2679     2679
124    MO  Solar Energy                2989     2989
125    MO   Wind Energy               23117    23117
126    MS       Biomass              64093    64093
127    MS    Geothermal                 958      958
128    MS    Hydropower                   0        0
129    MS  Solar Energy                2253     2253
130    MS   Wind Energy                   0        0
131    MT       Biomass              11496    11496
132    MT    Geothermal                 337      337
133    MT    Hydropower               29999    29999
134    MT  Solar Energy                1089     1089
135    MT   Wind Energy               15548    15548
136    NC       Biomass             127660   127660
137    NC    Geothermal                 967      967
138    NC    Hydropower               14417    14417
139    NC  Solar Energy               41955    41955
140    NC   Wind Energy                1805     1805
141    ND       Biomass              34539    34539
142    ND    Geothermal                 978      978
143    ND    Hydropower                7230     7230
144    ND  Solar Energy                  12       12
145    ND   Wind Energy               49395    49395
146    NE       Biomass             118507   118507
147    NE    Geothermal                1212     1212
148    NE    Hydropower                3900     3900
```

```
149    NE  Solar Energy              468      468
150    NE   Wind Energy            40416    40416
151    NH       Biomass            31020    31020
152    NH    Geothermal               29       29
153    NH    Hydropower             5431     5431
154    NH  Solar Energy             1105     1105
155    NH   Wind Energy             1404     1404
156    NJ       Biomass            55964    55964
157    NJ    Geothermal              466      466
158    NJ    Hydropower               40       40
159    NJ  Solar Energy            17876    17876
160    NJ   Wind Energy               63       63
161    NM       Biomass            17018    17018
162    NM    Geothermal              490      490
163    NM    Hydropower              368      368
164    NM  Solar Energy            11514    11514
165    NM   Wind Energy            50888    50888
166    NV       Biomass            13774    13774
167    NV    Geothermal            15709    15709
168    NV    Hydropower             4500     4500
169    NV  Solar Energy            39902    39902
170    NV   Wind Energy              994      994
171    NY       Biomass           135868   135868
172    NY    Geothermal             1185     1185
173    NY    Hydropower            97017    97017
174    NY  Solar Energy            22521    22521
175    NY   Wind Energy            16377    16377
176    OH       Biomass           131879   131879
177    OH    Geothermal             3435     3435
178    OH    Hydropower             1730     1730
179    OH  Solar Energy             6420     6420
180    OH   Wind Energy             9620     9620
181    OK       Biomass            53151    53151
182    OK    Geothermal               24       24
183    OK    Hydropower             5062     5062
184    OK  Solar Energy              856      856
185    OK   Wind Energy           126286   126286
186    OR       Biomass           104208   104208
187    OR    Geothermal             1833     1833
188    OR    Hydropower            89835    89835
189    OR  Solar Energy             9637     9637
190    OR   Wind Energy            30550    30550
191    PA       Biomass           149768   149768
192    PA    Geothermal             2162     2162
193    PA    Hydropower             9497     9497
194    PA  Solar Energy             5491     5491
195    PA   Wind Energy            11117    11117
196    RI       Biomass             9375     9375
```

```
197    RI    Geothermal               57       57
198    RI    Hydropower               26       26
199    RI  Solar Energy             3545     3545
200    RI   Wind Energy              576      576
201    SC       Biomass           122864   122864
202    SC    Geothermal              648      648
203    SC    Hydropower             7504     7504
204    SC  Solar Energy            11470    11470
205    SC   Wind Energy                0        0
206    SD       Biomass            77849    77849
207    SD    Geothermal             1868     1868
208    SD    Hydropower            14657    14657
209    SD  Solar Energy              177      177
210    SD   Wind Energy            31989    31989
211    TN       Biomass            84416    84416
212    TN    Geothermal              213      213
213    TN    Hydropower            27438    27438
214    TN  Solar Energy             3557     3557
215    TN   Wind Energy               55       55
216    TX       Biomass           266309   266309
217    TX    Geothermal             2478     2478
218    TX    Hydropower             2586     2586
219    TX  Solar Energy           110891   110891
220    TX   Wind Energy           408946   408946
221    UT       Biomass            15792    15792
222    UT    Geothermal             2371     2371
223    UT    Hydropower             2624     2624
224    UT  Solar Energy            16556    16556
225    UT   Wind Energy             2332     2332
226    VA       Biomass           155917   155917
227    VA    Geothermal             1701     1701
228    VA    Hydropower             4745     4745
229    VA  Solar Energy            21455    21455
230    VA   Wind Energy              160      160
231    VT       Biomass            14207    14207
232    VT    Geothermal               29       29
233    VT    Hydropower             5252     5252
234    VT  Solar Energy             1562     1562
235    VT   Wind Energy             1159     1159
236    WA       Biomass           126267   126267
237    WA    Geothermal             1136     1136
238    WA    Hydropower           209653   209653
239    WA  Solar Energy             3140     3140
240    WA   Wind Energy            25759    25759
241    WI       Biomass           132268   132268
242    WI    Geothermal              615      615
243    WI    Hydropower             6571     6571
244    WI  Solar Energy             5581     5581
```

```
245    WI   Wind Energy              5930     5930
246    WV       Biomass             15773    15773
247    WV    Geothermal               32       32
248    WV    Hydropower             5221     5221
249    WV  Solar Energy              214      214
250    WV   Wind Energy             7129     7129
251    WY       Biomass             4521     4521
252    WY    Geothermal              663      663
253    WY    Hydropower             3130     3130
254    WY  Solar Energy              692      692
255    WY   Wind Energy            29468    29468
256    US       Biomass          4914764  4914764
257    US    Geothermal           119346   119346
258    US    Hydropower           835948   835948
259    US  Solar Energy           880325   880325
260    US   Wind Energy          1436934  1436934
```

```
# Clean EV registration dataset

# Update column names and remove header rows
colnames(ev_data)
```

```
[1] "electric.vehicle.registrations_by_state..2023."
[2] "X"
```

```
head(ev_data)
```

```
  electric.vehicle.registrations_by_state..2023.          X
1
2                                           STATE Count-EVs
3                                         Alabama     #13047
4                                          Alaska      ~2697
5                                         Arizona      89798
6                                        Arkansas   7108 EVs
```

```
ev_data_clean <- ev_data %>%
  rename(state_name = electric.vehicle.registrations_by_state..2023.,
         registration_count = X) %>%
  slice(-c(1, 2))

# Extract numeric registration values
ev_registrations <- ev_data_clean %>%
  mutate(registrations = str_extract(registration_count, "\\d+"))
```

```r
## Clean energy pricing dataset
colnames(energy_prices)
```

```
[1] "V1"
```

```r
# Remove header rows
prices_clean <- energy_prices %>% slice(-c(1:2))

# Split combined column into separate year columns
colnames(prices_clean)
```

```
[1] "V1"
```

```r
prices_separated <- prices_clean %>%
  separate(V1, into = c("State", "year_2021", "year_2022", "year_2023"),
           sep = ",") %>%
  slice(-c(1))

# Extract decimal price values for each year
prices_final <- prices_separated %>%
  mutate(price_21 = str_extract(year_2021, "\\d+\\.\\d+"),
         price_22 = str_extract(year_2022, "\\d+\\.\\d+"),
         price_23 = str_extract(year_2023, "\\d+\\.\\d+")) %>%
  select(-c(2, 3, 4))

prices_final
```

```
   State price_21 price_22 price_23
1     AK    20.03    27.33    23.84
2     AL    17.85    23.37    21.11
3     AR    18.42    23.84    21.76
4     AZ    25.07    31.72    30.28
5     CA    28.44    37.35    35.72
6     CO    20.64    25.85    23.85
7     CT    25.85    33.15    32.32
8     DC    25.67    30.84    32.28
9     DE    21.83    27.74    26.70
10    FL    22.53    29.35    28.12
11    GA    19.77    25.51    22.97
12    HI    32.69    44.71    40.33
13    IA    16.39    20.48    18.09
14    ID    19.34    23.86    22.77
15    IL    18.35    23.98    21.60
16    IN    17.13    22.01    19.87
```

```
17    KS    19.06    24.67    22.19
18    KY    19.23    25.30    22.24
19    LA    12.48    15.99    12.42
20    MA    25.73    32.54    31.73
21    MD    23.64    29.98    28.85
22    ME    21.37    29.77    28.75
23    MI    19.38    23.37    22.37
24    MN    18.75    23.81    22.18
25    MO    20.50    26.10    24.70
26    MS    18.93    24.15    22.44
27    MT    20.62    25.59    24.05
28    NC    20.97    26.13    24.97
29    ND    15.59    19.98    18.15
30    NE    17.53    22.69    20.47
31    NH    25.83    34.11    32.28
32    NJ    21.79    27.11    25.20
33    NM    21.40    27.76    24.66
34    NV    21.11    28.94    28.58
35    NY    22.60    29.11    27.05
36    OH    18.48    23.26    21.65
37    OK    17.41    23.62    20.30
38    OR    21.46    26.92    26.55
39    PA    19.53    25.10    23.67
40    RI    25.61    31.84    31.52
41    SC    20.21    25.37    23.07
42    SD    18.85    23.68    21.31
43    TN    19.57    25.76    23.31
44    TX    16.38    20.78    17.37
45    UT    19.71    25.03    23.79
46    VA    19.72    25.57    23.81
47    VT    25.18    31.81    29.76
48    WA    20.95    26.93    26.35
49    WI    19.43    24.06    22.70
50    WV    19.57    25.49    24.29
51    WY    17.27    21.76    19.69
52    US    19.98    25.66    23.59
```

Part 3: Joining / Pivoting Datasets for Analysis

```
## Merge renewable energy datasets across years
head(renewable_21_clean)
```

```
  State Energy_Source Renewable_Use_2021 renew_21
1    AK       Biomass              ≈3153     3153
2    AK    Geothermal           186 MMBtu      186
3    AK    Hydropower          5763 about     5763
4    AK  Solar Energy                ~45       45
```

```
5    AK   Wind Energy            451 USD      451
6    AL       Biomass        198543 est.   198543
```

```r
# Combine 2021 and 2022 using left join
merged_21_22 <- left_join(renewable_21_clean, renewable_22_clean,
                          by = join_by(State == State,
                                       Energy_Source == Energy_Source)) %>%
  select(-c("Renewable_Use_2021", "Renewable_Use_2022"))

# Add 2023 data to the merged dataset
merged_all_years <- left_join(merged_21_22, renewable_23_clean,
                              by = join_by(State == State,
                                           Energy_Source == Energy_Source))
%>%
  select(-c("Renewable_Use_2023"))

merged_all_years
```

```
    State Energy_Source renew_21 renew_22 renew_23
1      AK       Biomass     3153     3846     3404
2      AK    Geothermal      186      186      186
3      AK    Hydropower     5763     5846     6051
4      AK  Solar Energy       45       57       67
5      AK   Wind Energy      451      475      380
6      AL       Biomass   198543   193932   189040
7      AL    Geothermal      141      141      141
8      AL    Hydropower    39309    34762    28762
9      AL  Solar Energy     1823     3200     4246
10     AL   Wind Energy        0        0        0
11     AR       Biomass    72939    74816    71311
12     AR    Geothermal      808      808      808
13     AR    Hydropower    13746    11835    11017
14     AR  Solar Energy     2221     3365     4141
15     AR   Wind Energy        0        0        0
16     AZ       Biomass    35287    36364    36572
17     AZ    Geothermal      345      345      345
18     AZ    Hydropower    20379    18075    20258
19     AZ  Solar Energy    37795    41092    45356
20     AZ   Wind Energy     5460     5338     5914
21     CA       Biomass   462829   497652   612607
22     CA    Geothermal    40106    40288    40578
23     CA    Hydropower    50080    60202   110485
24     CA  Solar Energy   205221   232908   253676
25     CA   Wind Energy    51784    49945    47833
26     CO       Biomass    36334    38711    35513
27     CO    Geothermal      759      759      759
```

```
28     CO    Hydropower     5453     4588     5447
29     CO  Solar Energy     9801    13159    18440
30     CO   Wind Energy    51609    57701    54903
31     CT       Biomass    42781    41972    40711
32     CT    Geothermal       21       21       21
33     CT    Hydropower     1629     1065     1588
34     CT  Solar Energy     4831     5982     6629
35     CT   Wind Energy       44       44       34
36     DC       Biomass     1897     1923     1984
37     DC    Geothermal       22       22       22
38     DC    Hydropower        0        0        0
39     DC  Solar Energy      568      678      790
40     DC   Wind Energy        0        0        0
41     DE       Biomass     5995     6160     6383
42     DE    Geothermal      430      430      430
43     DE    Hydropower        0        0        0
44     DE  Solar Energy      709      797     1213
45     DE   Wind Energy       17       15       14
46     FL       Biomass   221885   219011   187267
47     FL    Geothermal    10056    10056    10056
48     FL    Hydropower      858      788      765
49     FL  Solar Energy    64491    74750    88219
50     FL   Wind Energy        0        0        0
51     GA       Biomass   258089   256735   253485
52     GA    Geothermal      315      315      315
53     GA    Hydropower    12491    10840     9799
54     GA  Solar Energy    18218    25348    27863
55     GA   Wind Energy        0        0        0
56     HI       Biomass     8816     8806     8914
57     HI    Geothermal      635      719      665
58     HI    Hydropower      392      376      318
59     HI  Solar Energy     8046     8437     8985
60     HI   Wind Energy     2245     2134     2164
61     IA       Biomass   256935   258515   265747
62     IA    Geothermal     1281     1281     1281
63     IA    Hydropower     3344     3446     3235
64     IA  Solar Energy     1647     2404     3146
65     IA   Wind Energy   126579   156138   141392
66     ID       Biomass    33826    37284    35074
67     ID    Geothermal     1819     1814     1804
68     ID    Hydropower    27280    28523    28585
69     ID  Solar Energy     2358     2453     3749
70     ID   Wind Energy     9145     8331     7915
71     IL       Biomass   150154   155145   155910
72     IL    Geothermal     2042     2042     2042
73     IL    Hydropower      439      393      314
74     IL  Solar Energy     6190    10800    13028
75     IL   Wind Energy    65282    80161    74409
```

```
76     IN       Biomass   121697   126202   128816
77     IN    Geothermal     4647     4647     4647
78     IN    Hydropower     1321     1265     1582
79     IN  Solar Energy     2852     4803     7669
80     IN   Wind Energy    26808    34070    30177
81     KS       Biomass    46363    48860    45449
82     KS    Geothermal      974      974      974
83     KS    Hydropower      102       81       46
84     KS  Solar Energy      444      579      745
85     KS   Wind Energy    87667   101294    93054
86     KY       Biomass    51928    58773    55351
87     KY    Geothermal     2712     2712     2712
88     KY    Hydropower    16638    15456    13493
89     KY  Solar Energy      465      575     1047
90     KY   Wind Energy        0        0        0
91     LA       Biomass   128794   131549   132613
92     LA    Geothermal     1842     1842     1842
93     LA    Hydropower     3785     3126     2414
94     LA  Solar Energy     1484     1692     2113
95     LA   Wind Energy        0        0        0
96     MA       Biomass    55621    57545    56272
97     MA    Geothermal      859      859      859
98     MA    Hydropower     3813     2993     3976
99     MA  Solar Energy    14366    18568    19833
100    MA   Wind Energy      712      736      620
101    MD       Biomass    37402    35988    37140
102    MD    Geothermal      570      570      570
103    MD    Hydropower     7224     6072     6309
104    MD  Solar Energy     5772     6928     8049
105    MD   Wind Energy     1765     1698     1643
106    ME       Biomass    76566    71303    64238
107    ME    Geothermal       72       72       72
108    ME    Hydropower     8670    10452    13074
109    ME  Solar Energy     1153     2771     4080
110    ME   Wind Energy     8681     9268     7980
111    MI       Biomass   155433   161389   154360
112    MI    Geothermal     5193     5193     5193
113    MI    Hydropower     4571     4729     4760
114    MI  Solar Energy     2616     4276     5851
115    MI   Wind Energy    26262    31224    28294
116    MN       Biomass   163547   166428   162640
117    MN    Geothermal     1075     1075     1075
118    MN    Hydropower     2317     3243     2560
119    MN  Solar Energy     7304     7531     8462
120    MN   Wind Energy    41870    51491    49127
121    MO       Biomass    58533    62209    61275
122    MO    Geothermal      352      352      352
123    MO    Hydropower     5792     4721     2679
```

```
124    MO  Solar Energy     1906     2355     2989
125    MO   Wind Energy    22295    25674    23117
126    MS       Biomass    63655    63847    64093
127    MS    Geothermal      958      958      958
128    MS    Hydropower        0        0        0
129    MS  Solar Energy     1520     1809     2253
130    MS   Wind Energy        0        0        0
131    MT       Biomass    12290    12554    11496
132    MT    Geothermal      337      337      337
133    MT    Hydropower    31590    33731    29999
134    MT  Solar Energy      269      299     1089
135    MT   Wind Energy    11849    13723    15548
136    NC       Biomass   138045   138609   127660
137    NC    Geothermal      967      967      967
138    NC    Hydropower    19833    15990    14417
139    NC  Solar Energy    36370    40733    41955
140    NC   Wind Energy     1756     1866     1805
141    ND       Biomass    33921    33480    34539
142    ND    Geothermal      978      978      978
143    ND    Hydropower     6787     6112     7230
144    ND  Solar Energy        9       10       12
145    ND   Wind Energy    50959    55445    49395
146    NE       Biomass   120181   120119   118507
147    NE    Geothermal     1212     1212     1212
148    NE    Hydropower     3832     3608     3900
149    NE  Solar Energy      322      404      468
150    NE   Wind Energy    32728    43039    40416
151    NH       Biomass    32487    33184    31020
152    NH    Geothermal       29       29       29
153    NH    Hydropower     3497     4099     5431
154    NH  Solar Energy      745      906     1105
155    NH   Wind Energy     1720     1646     1404
156    NJ       Biomass    53825    54827    55964
157    NJ    Geothermal      466      466      466
158    NJ    Hydropower       62       18       40
159    NJ  Solar Energy    15619    17803    17876
160    NJ   Wind Energy       67       74       63
161    NM       Biomass    17390    18132    17018
162    NM    Geothermal      542      528      490
163    NM    Hydropower      419      412      368
164    NM  Solar Energy     7757     8962    11514
165    NM   Wind Energy    36101    49251    50888
166    NV       Biomass    13735    14392    13774
167    NV    Geothermal    14914    14913    15709
168    NV    Hydropower     6634     5752     4500
169    NV  Solar Energy    27204    36601    39902
170    NV   Wind Energy     1160     1077      994
171    NY       Biomass   135921   140237   135868
```

```
172    NY    Geothermal     1185     1185     1185
173    NY    Hydropower    98148    93596    97017
174    NY  Solar Energy    14542    19281    22521
175    NY   Wind Energy    14182    15584    16377
176    OH       Biomass   129100   134824   131879
177    OH    Geothermal     3435     3435     3435
178    OH    Hydropower     1973     1730     1730
179    OH  Solar Energy     3524     4531     6420
180    OH   Wind Energy     8826    10761     9620
181    OK       Biomass    56130    54864    53151
182    OK    Geothermal       24       24       24
183    OK    Hydropower     9438     6038     5062
184    OK  Solar Energy      466      598      856
185    OK   Wind Energy   111028   128130   126286
186    OR       Biomass    89886    93054   104208
187    OR    Geothermal     1856     1842     1833
188    OR    Hydropower    94374   106810    89835
189    OR  Solar Energy     7437     8257     9637
190    OR   Wind Energy    31990    27805    30550
191    PA       Biomass   151173   154330   149768
192    PA    Geothermal     2162     2162     2162
193    PA    Hydropower    10696     9051     9497
194    PA  Solar Energy     3768     4319     5491
195    PA   Wind Energy    11789    12188    11117
196    RI       Biomass     8808     9395     9375
197    RI    Geothermal       57       57       57
198    RI    Hydropower       15       25       26
199    RI  Solar Energy     2331     3073     3545
200    RI   Wind Energy      587      714      576
201    SC       Biomass   125195   127166   122864
202    SC    Geothermal      648      648      648
203    SC    Hydropower     8679     7440     7504
204    SC  Solar Energy     9273    10073    11470
205    SC   Wind Energy        0        0        0
206    SD       Biomass    76673    78433    77849
207    SD    Geothermal     1868     1868     1868
208    SD    Hydropower    17000    14530    14657
209    SD  Solar Energy       19       20      177
210    SD   Wind Energy    31822    35127    31989
211    TN       Biomass    96952    82232    84416
212    TN    Geothermal      213      213      213
213    TN    Hydropower    37093    31384    27438
214    TN  Solar Energy     1487     2593     3557
215    TN   Wind Energy       96       51       55
216    TX       Biomass   249311   268045   266309
217    TX    Geothermal     2478     2478     2478
218    TX    Hydropower     3693     2116     2586
219    TX  Solar Energy    59311    87388   110891
```

```
220    TX   Wind Energy   339406   391653   408946
221    UT       Biomass    15136    14627    15792
222    UT    Geothermal     2240     2389     2371
223    UT    Hydropower     1684     2031     2624
224    UT  Solar Energy    14174    15854    16556
225    UT   Wind Energy     2816     2468     2332
226    VA       Biomass   155498   162230   155917
227    VA    Geothermal     1701     1701     1701
228    VA    Hydropower     4455     3880     4745
229    VA  Solar Energy    12792    17653    21455
230    VA   Wind Energy      169      174      160
231    VT       Biomass    15197    15188    14207
232    VT    Geothermal       29       29       29
233    VT    Hydropower     3729     3892     5252
234    VT  Solar Energy     1322     1504     1562
235    VT   Wind Energy     1154     1396     1159
236    WA       Biomass   116292   118813   126267
237    WA    Geothermal     1136     1136     1136
238    WA    Hydropower   243546   269263   209653
239    WA  Solar Energy     1354     1754     3140
240    WA   Wind Energy    31724    27504    25759
241    WI       Biomass   130446   133538   132268
242    WI    Geothermal      615      615      615
243    WI    Hydropower     7318     6793     6571
244    WI  Solar Energy     2119     3749     5581
245    WI   Wind Energy     5437     6195     5930
246    WV       Biomass    14909    15724    15773
247    WV    Geothermal       32       32       32
248    WV    Hydropower     5816     5620     5221
249    WV  Solar Energy      129      166      214
250    WV   Wind Energy     5542     6848     7129
251    WY       Biomass     4876     4790     4521
252    WY    Geothermal      663      663      663
253    WY    Hydropower     2697     2541     3130
254    WY  Solar Energy      674      715      692
255    WY   Wind Energy    28824    33370    29468
256    US       Biomass  4752482  4873241  4914764
257    US    Geothermal   118007   118389   119346
258    US    Hydropower   858407   869339   835948
259    US  Solar Energy   626863   764563   880325
260    US   Wind Energy  1290407  1481823  1436934
```

```
## Aggregate renewable energy totals by state for each year
state_renewable_totals <- merged_all_years %>%
  mutate(across(starts_with("renew_"), as.numeric)) %>%
  group_by(State) %>%
  summarize(
```

```
    year_2021_total = sum(renew_21, na.rm = TRUE),
    year_2022_total = sum(renew_22, na.rm = TRUE),
    year_2023_total = sum(renew_23, na.rm = TRUE)
  )

state_renewable_totals
```

```
# A tibble: 52 × 4
   State year_2021_total year_2022_total year_2023_total
   <chr>           <dbl>           <dbl>           <dbl>
 1 AK               9598           10410           10088
 2 AL             239816          232035          222189
 3 AR              89714           90824           87277
 4 AZ              99266          101214          108445
 5 CA             810020          880995         1065179
 6 CO             103956          114918          115062
 7 CT              49306           49084           48983
 8 DC               2487            2623            2796
 9 DE               7151            7402            8040
10 FL             297290          304605          286307
# ℹ 42 more rows
```

```
## Reshape total energy usage dataframes to long format
total_21_long <- total_21 %>%
  pivot_longer(cols = -Energy_Source,
               names_to = "State",
               values_to = "total_usage_2021") %>%
  group_by(State) %>%
  arrange(State)

## Apply same transformation for 2022 and 2023
total_22_long <- total_22 %>%
  pivot_longer(cols = -Energy_Source,
               names_to = "State",
               values_to = "total_usage_2022") %>%
  group_by(State) %>%
  arrange(State)

total_23_long <- total_23 %>%
  pivot_longer(cols = -Energy_Source,
               names_to = "State",
               values_to = "total_usage_2023") %>%
  group_by(State) %>%
  arrange(State)
```

Part 4: Mapping Visualization

```
library(maps)
```

```

Attaching package: 'maps'
```

```
The following object is masked from 'package:purrr':

    map
```

```
library(ggplot2)
# Calculate total energy usage by state for each year
total_energy_by_state <- total_21_long %>%
  group_by(State) %>%
  summarize(total_2021 = sum(total_usage_2021, na.rm = TRUE))

total_energy_22 <- total_22_long %>%
  group_by(State) %>%
  summarize(total_2022 = sum(total_usage_2022, na.rm = TRUE))

total_energy_23 <- total_23_long %>%
  group_by(State) %>%
  summarize(total_2023 = sum(total_usage_2023, na.rm = TRUE))

# Join all total energy data
total_energy_all <- total_energy_by_state %>%
  left_join(total_energy_22, by = "State") %>%
  left_join(total_energy_23, by = "State")

# Join renewable totals with total energy usage
energy_combined <- state_renewable_totals %>%
  left_join(total_energy_all, by = "State")

# Calculate renewable energy percentage for each year
energy_combined <- energy_combined %>%
  mutate(
    renewable_pct_2021 = (year_2021_total / total_2021) * 100,
    renewable_pct_2022 = (year_2022_total / total_2022) * 100,
    renewable_pct_2023 = (year_2023_total / total_2023) * 100,
    # Convert state names to lowercase for map joining
    state_lower = str_to_lower(State)
  )

# Join with energy prices
energy_combined <- energy_combined %>%
```

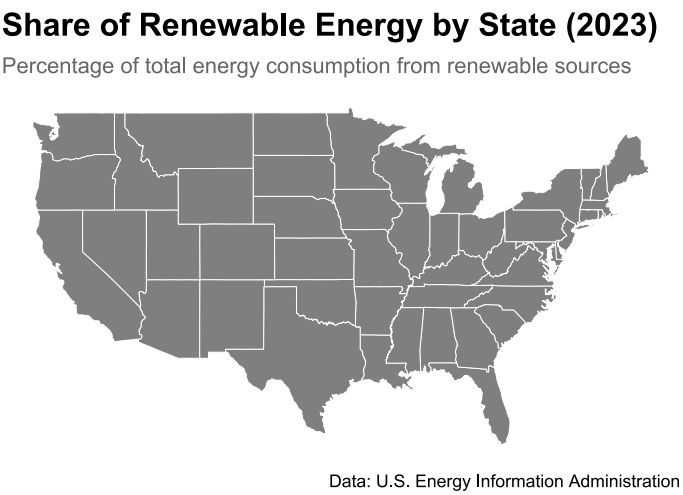
```
  left_join(prices_final, by = "State") %>%
  mutate(across(starts_with("price_"), as.numeric))

# View the combined dataset
head(energy_combined)
```

```
# A tibble: 6 × 14
  State year_2021_total year_2022_total year_2023_total total_2021 total_2022
  <chr>           <dbl>           <dbl>           <dbl>      <int>      <int>
1 AK               9598           10410           10088     684975     730276
2 AL             239816          232035          222189    2352656    2337513
3 AR              89714           90824           87277    1136025    1178115
4 AZ              99266          101214          108445    1681257    1651857
5 CA             810020          880995         1065179    6142252    6244174
6 CO             103956          114918          115062    1364155    1411476
# ℹ 8 more variables: total_2023 <int>, renewable_pct_2021 <dbl>,
#   renewable_pct_2022 <dbl>, renewable_pct_2023 <dbl>, state_lower <chr>,
#   price_21 <dbl>, price_22 <dbl>, price_23 <dbl>
```

```
## Create the map

# Get US state map data
us_states <- map_data("state")

# Join map data with our energy data
map_data_renewable <- us_states %>%
  left_join(energy_combined, by = c("region" = "state_lower"))

# Map 1: Renewable Energy Share in 2023
ggplot(map_data_renewable, aes(x = long, y = lat, group = group,
                               fill = renewable_pct_2023)) +
  geom_polygon(color = "white", size = 0.2) +
  coord_fixed(1.3) +
  scale_fill_viridis_c(option = "plasma",
                       name = "Renewable\nEnergy %",
                       na.value = "grey50") +
  labs(
    title = "Share of Renewable Energy by State (2023)",
    subtitle = "Percentage of total energy consumption from renewable
sources",
    caption = "Data: U.S. Energy Information Administration"
  ) +
  theme_minimal() +
  theme(
    axis.text = element_blank(),
    axis.title = element_blank(),
```

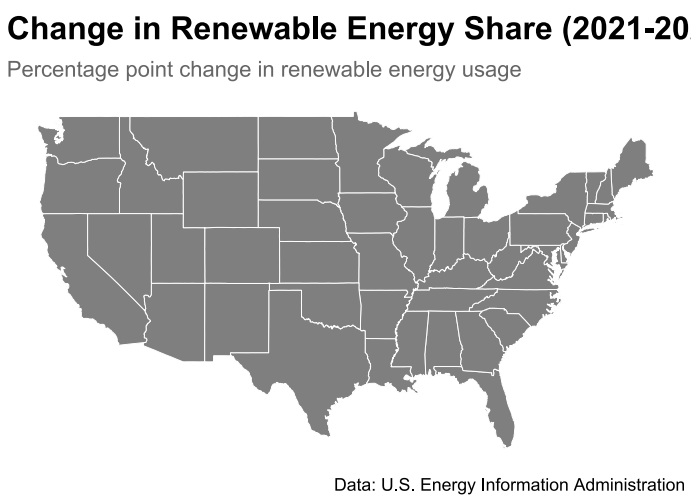
```
    axis.ticks = element_blank(),
    panel.grid = element_blank(),
    plot.title = element_text(size = 16, face = "bold"),
    plot.subtitle = element_text(size = 11, color = "grey40")
  )
```

```
Warning: Using `size` aesthetic for lines was deprecated in ggplot2 3.4.0.
ℹ Please use `linewidth` instead.
```



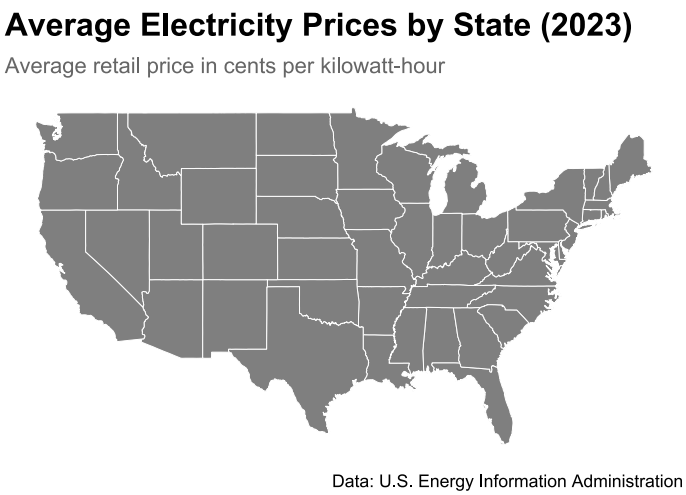

```
# Map 2: Change in Renewable Energy Share (2021 to 2023)
map_data_renewable <- map_data_renewable %>%
  mutate(renewable_change = renewable_pct_2023 - renewable_pct_2021)

ggplot(map_data_renewable, aes(x = long, y = lat, group = group,
                               fill = renewable_change)) +
  geom_polygon(color = "white", size = 0.2) +
  coord_fixed(1.3) +
  scale_fill_gradient2(
    low = "red",
    mid = "white",
    high = "darkgreen",
    midpoint = 0,
    name = "Change in\nRenewable %",
    na.value = "grey50"
  ) +
  labs(
    title = "Change in Renewable Energy Share (2021-2023)",
    subtitle = "Percentage point change in renewable energy usage",
    caption = "Data: U.S. Energy Information Administration"
  ) +
```

```
  theme_minimal() +
  theme(
    axis.text = element_blank(),
    axis.title = element_blank(),
    axis.ticks = element_blank(),
    panel.grid = element_blank(),
    plot.title = element_text(size = 16, face = "bold"),
    plot.subtitle = element_text(size = 11, color = "grey40")
  )
```



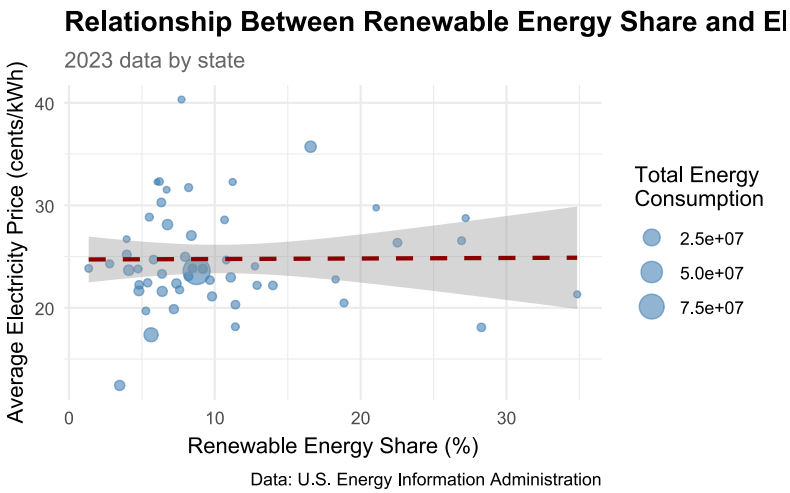

```
# Map 3: Electricity Prices in 2023
ggplot(map_data_renewable, aes(x = long, y = lat, group = group,
                               fill = price_23)) +
  geom_polygon(color = "white", size = 0.2) +
  coord_fixed(1.3) +
  scale_fill_viridis_c(option = "mako",
                       name = "Price\n(cents/kWh)",
                       na.value = "grey50") +
  labs(
    title = "Average Electricity Prices by State (2023)",
    subtitle = "Average retail price in cents per kilowatt-hour",
    caption = "Data: U.S. Energy Information Administration"
  ) +
  theme_minimal() +
  theme(
    axis.text = element_blank(),
    axis.title = element_blank(),
    axis.ticks = element_blank(),
    panel.grid = element_blank(),
    plot.title = element_text(size = 16, face = "bold"),
```

```
    plot.subtitle = element_text(size = 11, color = "grey40")
  )
```




```
# Scatter plot: Renewable Energy vs Price
ggplot(energy_combined, aes(x = renewable_pct_2023, y = price_23)) +
  geom_point(aes(size = total_2023), alpha = 0.6, color = "steelblue") +
  geom_smooth(method = "lm", se = TRUE, color = "darkred", linetype =
"dashed") +
  labs(
    title = "Relationship Between Renewable Energy Share and Electricity
Prices",
    subtitle = "2023 data by state",
    x = "Renewable Energy Share (%)",
    y = "Average Electricity Price (cents/kWh)",
    size = "Total Energy\nConsumption",
    caption = "Data: U.S. Energy Information Administration"
  ) +
  theme_minimal() +
  theme(
    plot.title = element_text(size = 14, face = "bold"),
    plot.subtitle = element_text(size = 11, color = "grey40")
  )
```

```
`geom_smooth()` using formula = 'y ~ x'
```




```
# Calculate correlation
correlation <- cor(energy_combined$renewable_pct_2023,
                   energy_combined$price_23,
                   use = "complete.obs")
cat("Correlation between renewable share and price:", round(correlation, 3))
```

```
Correlation between renewable share and price: 0.007
```