

Clean Energy and Electric Vehicles: Which States Are Best Positioned for Clean EV Charging?

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2025-10-29

Overview

This analysis addresses the main research question: “Electric vehicles reduce direct emissions, but does the electricity used to charge them actually come from clean sources?”

My specific sub-question focuses on **“Which states are best positioned for clean EV charging?”** - examining the relationship between renewable energy infrastructure and EV adoption across US states. This is critical because EVs are only as clean as the electricity grid they charge from.

Data and Methods

Data Sources

The analysis uses four datasets from 2021-2023: - Electric Vehicle registrations by state (2023) - Renewable energy use by state and source - Total energy use by state and source - Average energy prices by state

Data Cleaning and Preparation

```
# Load and clean EV data
ev_data <- read_csv("data/ev-registrations-by-state-2023.csv", skip = 1) %>%
  rename(state = 1, ev_count = 2) %>%
  filter(state != "STATE") %>%
  mutate(ev_count = str_remove_all(ev_count, "[#~EVs ]"),
```

```

    ev_count = as.numeric(ev_count))

# Load total energy data for 2023
total_2023 <- read_csv("data/total-use-2023.csv")

# Get renewable energy by state
renewable_by_state <- total_2023 %>%
  filter(Energy_Source == "total renewable-energy") %>%
  pivot_longer(cols = -Energy_Source, names_to = "state_abbr", values_to = "renewable_energy") %>%
  filter(state_abbr != "US") %>%
  select(state_abbr, renewable_energy)

# Calculate total energy by state
total_by_state <- total_2023 %>%
  pivot_longer(cols = -Energy_Source, names_to = "state_abbr", values_to = "energy_value") %>%
  filter(state_abbr != "US") %>%
  group_by(state_abbr) %>%
  summarize(total_energy = sum(energy_value, na.rm = TRUE))

# Clean price data
price_data <- read_csv("data/av-energy-price-2021-2023.csv", skip = 2) %>%
  separate(1, into = c("state", "price_2021", "price_2022", "price_2023"), sep = ",") %>%
  mutate(price_2023_clean = as.numeric(str_extract(price_2023, "[0-9.]+")),
         state = str_trim(state))

```

Joining Datasets

```

# Create state lookup table
state_lookup <- data.frame(
  state_abbr = state.abb,
  state = state.name
) %>%
  add_row(state_abbr = "DC", state = "District of Columbia")

# Calculate renewable percentage and join all data
final_data <- total_by_state %>%
  left_join(renewable_by_state, by = "state_abbr") %>%
  mutate(renewable_percent = (renewable_energy / total_energy) * 100) %>%
  left_join(state_lookup, by = "state_abbr") %>%
  left_join(ev_data, by = "state") %>%

```

```

left_join(price_data %>% select(state, price_2023_clean), by = "state") %>%
filter(!is.na(state)) %>%
mutate(
  ev_per_million_btu = (ev_count / total_energy) * 1000000,
  clean_ev_score = renewable_percent * log(ev_count + 1)
)

# Show sample of joined data
head(final_data %>%
  select(state, renewable_percent, ev_count, total_energy, price_2023_clean) %>%
  arrange(desc(renewable_percent))) %>%
kable(digits = 1, caption = "Top States by Renewable Energy Percentage")

```

Table 1: Top States by Renewable Energy Percentage

state	renewable_percent	ev_count	total_energy	price_2023_clean
South Dakota	34.8	1675	363161	NA
Iowa	28.3	9031	1466926	NA
Maine	27.2	7377	328875	NA
Oregon	26.9	64361	876891	NA
Washington	22.5	152101	1624957	NA
Vermont	21.1	7816	105445	NA

Map Visualization

Renewable Energy Percentage by State

```

# Get US state map data
states_map <- map_data("state") %>%
  mutate(state = str_to_title(region))

# Join with our data
map_data <- states_map %>%
  left_join(final_data, by = "state")

# Create choropleth map
ggplot(map_data, aes(x = long, y = lat, group = group)) +
  geom_polygon(aes(fill = renewable_percent), color = "white", size = 0.2) +
  scale_fill_gradient2(

```

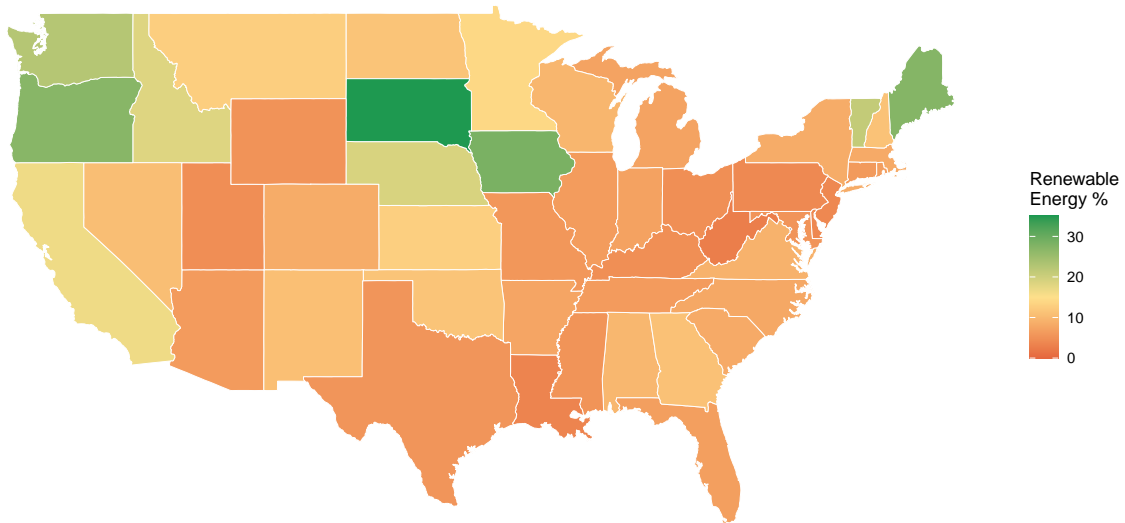
```

low = "#d73027",
mid = "#fee08b",
high = "#1a9850",
midpoint = 15,
name = "Renewable\nEnergy %",
limits = c(0, 35),
breaks = c(0, 10, 20, 30)
) +
coord_fixed(1.3) +
theme_minimal() +
labs(
  title = "Which States Are Best Positioned for Clean EV Charging?",
  subtitle = "Percentage of Total Energy from Renewable Sources (2023)",
  caption = "Source: US Energy Information Administration"
) +
theme(
  plot.title = element_text(size = 16, face = "bold", hjust = 0.5),
  plot.subtitle = element_text(size = 12, hjust = 0.5),
  legend.position = "right",
  panel.grid = element_blank(),
  axis.text = element_blank(),
  axis.title = element_blank(),
  axis.ticks = element_blank()
)

```

Which States Are Best Positioned for Clean EV Charging?

Percentage of Total Energy from Renewable Sources (2023)

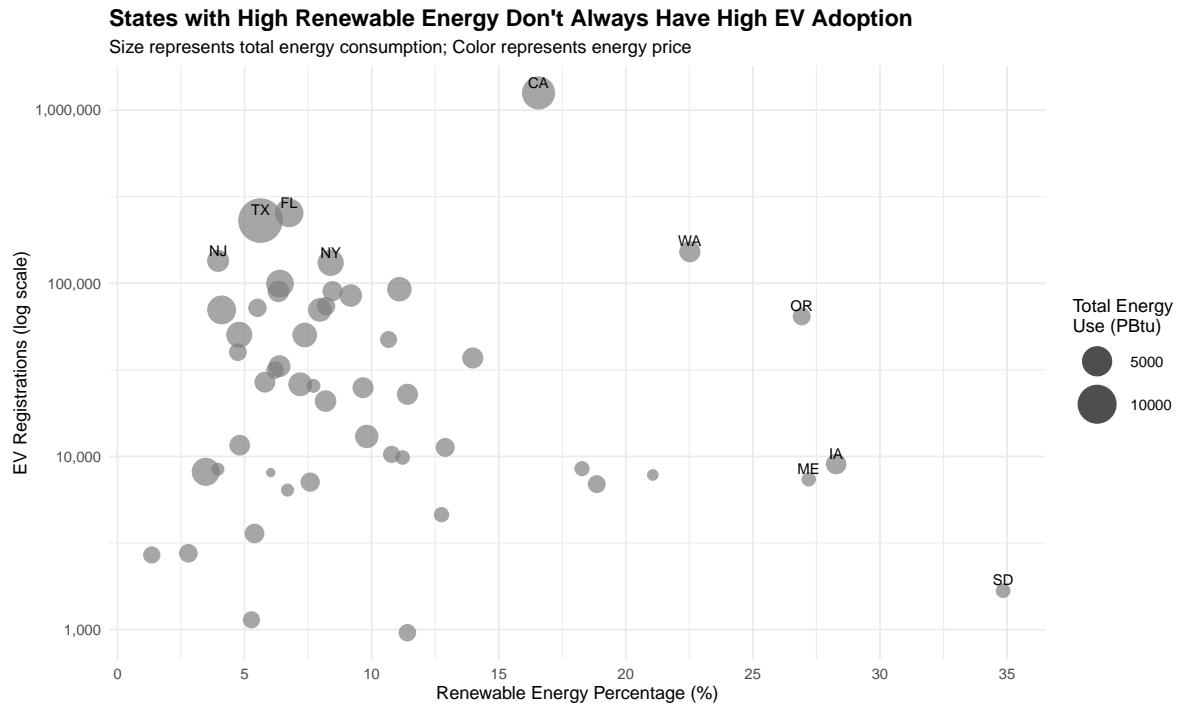


Source: US Energy Information Administration

EV Adoption vs Clean Energy Mix

```
ggplot(final_data, aes(x = renewable_percent, y = ev_count)) +
  geom_point(aes(size = total_energy/1000, color = price_2023_clean), alpha = 0.7) +
  geom_text(
    data = final_data %>% filter(ev_count > 100000 | renewable_percent > 25),
    aes(label = state_abbr),
    vjust = -0.5, size = 3
  ) +
  scale_y_log10(labels = scales::comma) +
  scale_x_continuous(breaks = seq(0, 35, 5)) +
  scale_color_gradient(low = "#1a9850", high = "#d73027", name = "Energy Price\n($/MMBtu)")
  scale_size_continuous(name = "Total Energy\nUse (PBtu)", range = c(2, 12)) +
  labs(
    x = "Renewable Energy Percentage (%)",
    y = "EV Registrations (log scale)",
    title = "States with High Renewable Energy Don't Always Have High EV Adoption",
    subtitle = "Size represents total energy consumption; Color represents energy price"
  ) +
  theme_minimal() +
```

```
theme(
  plot.title = element_text(size = 14, face = "bold"),
  legend.position = "right"
)
```



Analysis

Key Findings

```
# Best positioned states (high renewable % AND good EV adoption)
best_states <- final_data %>%
  filter(renewable_percent > 20 & ev_count > 5000) %>%
  arrange(desc(clean_ev_score)) %>%
  select(state, renewable_percent, ev_count, clean_ev_score) %>%
  head(8)

kable(best_states,
  col.names = c("State", "Renewable %", "EV Count", "Clean EV Score"),
  digits = 1,
  caption = "Best Positioned States for Clean EV Charging")
```

Table 2: Best Positioned States for Clean EV Charging

State	Renewable %	EV Count	Clean EV Score
Oregon	26.9	64361	298.1
Washington	22.5	152101	268.7
Iowa	28.3	9031	257.6
Maine	27.2	7377	242.2
Vermont	21.1	7816	188.8

```
# States with mismatched renewable energy and EV adoption
high_renewable_low_ev <- final_data %>%
  filter(renewable_percent > 25 & ev_count < 10000) %>%
  select(state, renewable_percent, ev_count)

high_ev_low_renewable <- final_data %>%
  filter(ev_count > 50000 & renewable_percent < 10) %>%
  select(state, renewable_percent, ev_count)
```

Patterns Observed

1. **Geographic Clustering:** States in the Pacific Northwest (Washington, Oregon) show both high renewable energy percentages and strong EV adoption, making them ideal for clean EV charging.
2. **Renewable Energy Leaders:** South Dakota (34.8%), Iowa (28.3%), and Maine (27.2%) lead in renewable energy percentage but have relatively low EV adoption, suggesting untapped potential.
3. **EV Adoption Leaders:** California has by far the most EVs (1.26 million) but only moderate renewable energy (16.6%). This means many California EVs are charged with fossil fuel-based electricity.
4. **Price Influence:** States with lower energy prices tend to have higher EV adoption, though this relationship is complex and influenced by other factors like state policies and urban density.

Answering the Main Question

The analysis reveals a critical insight: **Most electric vehicles in the US are NOT charged with predominantly clean energy.** While EVs eliminate tailpipe emissions, their environmental benefit is limited by the electricity grid's energy mix.

Best positioned states for truly clean EV transportation are: - **Washington:** 22.5% renewable energy, 152,101 EVs - **Oregon:** 26.9% renewable energy, 64,361 EVs
- **California:** Despite having the most EVs, only 16.6% renewable energy

Recommendations: 1. States with high renewable energy should incentivize EV adoption
2. States with high EV adoption should accelerate renewable energy deployment
3. Federal coordination could help match EV infrastructure investment with clean energy development

The transition to electric vehicles must be coupled with a transition to renewable electricity generation to achieve meaningful emissions reductions.