Preliminary Project Proposal

Basics:

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Preliminary Project Title: Exploring the Impact of Renewable Energy Investment on Fossil Fuel Electricity Generation in the United States

Background & Question

As the importance of climate change grows, the global energy sector has come under close examination. One urgent topic is the need to reduce carbon emissions by shifting from fossil fuels to renewable energy sources. Despite growing investments in solar, wind, and hydroelectric power, fossil fuels like coal and natural gas still dominate U.S. electricity generation. This raises a crucial question: *Does an increase in renewable energy generation notably reduce fossil fuel-based electricity generation at the state level in the United States?*

Many studies have surveyed national-level energy transitions (IEA, 2023; Carley & Konisky, 2020) or the performance of individual renewable sectors (IRENA, 2022), yet few examine whether clean energy adoption truly displaces fossil generation at the state level. Comprehending this dynamic can lead policymakers in allotting subsidies, modernizing grid infrastructure, and establishing realistic decarbonization timelines.

This question is worth exploring because the answer has both environmental and economic implications. If renewables are in fact crowding out fossil fuels, that supports combative clean energy policies. If not, it may indicate structural restrictions—like demand growth, market resistance, or storage shortfalls—that need attention.

While the subject of energy transitions is well-used, this specific framing—*state-level tradeoff patterns between renewable and fossil generation using recent multi-year data*— offers a new outlook. Thus, the question is both reasonably original and relevant within its scope.

Hypothesis & Prediction

Hypothesis: Increases in renewable energy generation in a U.S. state are associated with decreases in fossil fuel electricity generation over time.

Prediction: States with higher year year-over-year growth in renewable electricity generation will show a statistically significant negative correlation with fossil fuel-based electricity generation, suggesting displacement is occurring.

Data & Analysis

Dataset:

We will use the **U.S. Energy Information Administration (EIA)**'s "Net Generation by State by Type of Producer by Energy Source" dataset. It provides detailed annual electricity generation (in MWh) by energy source (e.g., solar, wind, coal, natural gas, etc.) from 1990 to the most recent available year.

Link: https://www.eia.gov/electricity/data/state/

> **EIA-923 Power Plant Operations Report (released: 10/4/2024)**
> Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923)[1]
> *Date range:* 1990 – 2023

Available formats: XLS

This dataset is ideal because it offers granular, multi-decade data on generation by energy type and geography, allowing for a robust longitudinal state-level analysis.

Outcome Variable:

Fossil fuel-based electricity generation per state per year (combined coal, natural gas, petroleum).

Predictor Variable(s):

- Renewable electricity generation (solar, wind, hydro, geothermal, biomass)
- Time (year)
- State-specific fixed effects
    - **Renewable Portfolio Standards (RPS)**: State laws that require utilities to generate or purchase a certain percentage of electricity from renewable sources.
    - **Net Metering Policies**: Allows consumers (homes/businesses) with solar panels to send excess electricity back to the grid and get credited.
    - **Energy Storage Incentives**: Policies or subsidies to promote grid-scale or residential battery storage
    - **Carbon Pricing / Emissions Trading**: Assigning a cost to carbon emissions through a carbon tax or cap-and-trade system.
    - **Utility Decoupling and Grid Modernization Mandates**: Decoupling separates utility profits from electricity sales volume, promoting efficiency and renewables.
    - **Coal Phase-Out Targets**: State commitments to close coal plants by a certain year.
- Possible control variables: population, total electricity demand, GDP per state (if available)

Analysis Plan:

1. Clean and filter the EIA data for the years 2010-2023 for all U.S. states.
2. Calculate total annual MWh for fossil fuels and renewables by state.
3. Use **panel data aggregation (fixed effects model)** to estimate whether increases in renewable generation predict decreases in fossil fuel use, controlling for time and state-specific differences.
4. Optionally visualize key trends (e.g., line plots or scatterplots of states with high renewable adoption like California vs. those with low uptake).

Potential Pitfalls:

- Some states may experience concurrent increases in both fossil and renewable generation due to rising electricity demand, confounding the results.
- Incomplete control for economic or policy variables may bias causal inference.
- Non-linearity: relationships may vary by source (e.g. , wind may displace coal more than hydro).

Success Criteria:

The question is considered “answered” if we can determine whether or not renewable generation growth statistically predicts fossil fuel reduction.
The hypothesis is supported if the regression results show a significant **negative** coefficient between renewable MWh and fossil fuel MWh per state-year.

Technical Details:

Programming Language:

Python (with pandas, statsmodels, matplotlib, seaborn for EDA and regression analysis)

Other Tools/Resources:

Jupyter Notebook, EIA Excel/CSV files, optional census datasets for state-level controls (e.g., demand/population)

Github Repository:

[TaxMuttle/DSE6311]

GenAI

- We used ChatGPT
- Prompt: ***Background & Question***
  - A defined research question that serves a need or fills a niche
    - What is the question?
    - What need or niche does it fill?
    - Why is it worth your time/effort to explore this question?
    - Is your question novel / original? If not, why not? (**Sometimes this is okay.**)
  - A hypothesis and prediction. Remember, these are not the same thing.
    - Generating hypotheses and predictions can be tricky. You will not be penalized if you don't get it right the first time. We will work on this together.

Data & Analysis

- What data set(s) have you found that you think are a good match for your question. Why?
  - Make sure to provide a link to a data source.
- What response / outcome variable will you use?
- What predictor variable(s) will you use?
- What is your tentative analysis plan?

        - Are there any pitfalls you can see with this plan? Anything that could topple your idea?
    - How will you know if your question is answered?
    - How will you know if your hypothesis is supported?

Technical Details

- What language do you plan to code in?
- Are there any other resources will you need?
- What is the link to your GitHub repo?

Please have the topic revolve around Energy.

- We validated by checking with Gemini

Sources:

1. **International Energy Agency.** *World Energy Outlook 2023*. IEA, 2023, https://www.iea.org/reports/world-energy-outlook-2023.

2. Carley, Sanya, and David M. Konisky. "The Justice and Equity Implications of the Clean Energy Transition." *Energy Policy*, vol. 143, 2020, 111726. Elsevier, https://doi.org/10.1016/j.enpol.2020.111726.

3. **International Renewable Energy Agency (IRENA).** *Renewable Power Generation Costs in 2022*. IRENA, 2022, https://www.irena.org/Publications.