Capstone Project Report

Weather API / Historical Data Analysis

Project Summary

This project aims to collect historical climate and emissions data by province annually and analyze them to uncover trends and predict future weather conditions. The project explores regional climate change patterns in Canada. Leveraging advanced analytical techniques, including per capita emissions efficiency, and lagged correlation sensitivity, the platform highlights meaningful relationships between population, emissions, and temperature trends. Also, the project combines the historical data with real-time weather data by using API from weatherapi.com, allowing a dynamic future and providing users with an interface.

1.Motivation

Climate change is one of the most pressing global challenges, yet much of the available climate data remains difficult to interpret for non-experts. While platforms like NASA EarthData, AQICN, and Climate.gov provide extensive climate datasets, they are primarily designed for researchers, scientists, and policymakers, often requiring advanced data analysis skills to extract meaningful insights.

This project aims to bridge this gap by developing an accessible and interactive Climate Data Visualization Platform that simplifies complex datasets, making them understandable for the general public, educators, and policy advisors who may not have a technical background.

2.Primary Goal

1. **User Interface:** Present real-time weather for major provinces in Canada. Connecting the user interface with API key. Also providing historical data based on user input.

2. **Historical & Predictive Analysis:** Based on weather data, for example, mean/min/max temperature and emission, predicts the future temperature and finds correlation between temperature and emission/population growth.

3.Key Points

1. How has the climate inclined over the past 70 years?

2. What factors cause temperature to rise?

3. What are the necessary means that human beings need to accomplish in order to prevent global warming?

4.Data Source & Selection

1. Global historical temperature recorded based on stations from NOAA
2. Census data in quarters by province from Statistics Canada
3. Greenhouse gases emissions by stations from Statistic Canada

5.Data preprocess

1. **Historical weather data based on stations:**

   1). Remove all data that are not from the Canada stations
   2). Merge the data on date/province
   3). Compute the annual temperature data for each province, removing outliers (extreme cases which have fewer stations)

2. **Census data by province:**

   1). Fill out missing data by using linear regression model (only 1950 and 1951)
   2). Combine the quarterly data into annually data

3. **Greenhouse gases emissions dataset:**

   1). Merge the data based on province and year

Greenhouse gases emissions datasets model usage: The emissions dataset originally only included records from **2004 to 2023,** which created a gap when aligning it with census and climate data spanning from **1950 to 2023**. To ensure consistency across datasets and enable comprehensive historical analysis, a **RandomForestRegressor** model was applied to predict missing emissions data from 1950 to 2003. This machine learning approach was selected for its robustness in handling nonlinear relationships and complex interactions. Several features were used in the model to improve accuracy, including:

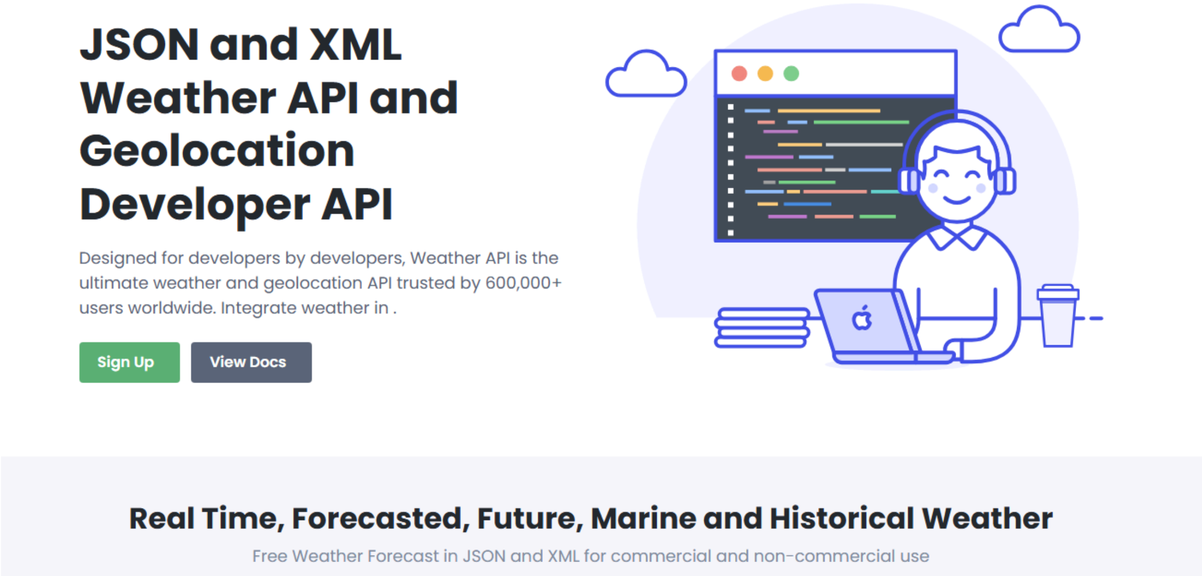
1. Annual mean temperature
2. Max temperature
3. Min temperature
4. Population growth
5. Number of stations

Final dataset: As shown in the picture, after preprocess step, merging three datasets

	0	1	2	3	4	5	6	7	8
0	Province	Year	Annual_Mean_Temp	Annual_Max_Temp	Annual_Min_Temp	Station_Count	GEO	Population	Emissions
1	Alberta	1950	1.25	36.7	-46.1	96	Alberta	919744	126123277.23779942
2	Alberta	1951	0.88	38.9	-44.4	96	Alberta	939834	126537786.10699905
3	Alberta	1952	4.11	36.1	-36.7	104	Alberta	971500	125604712.69819643
4	Alberta	1953	4.39	38.9	-33.3	112	Alberta	1010250	125816395.91237015
5	Alberta	1954	3.08	40.0	-38.9	111	Alberta	1054250	126501286.58305414
6	Alberta	1955	1.35	38.3	-43.3	117	Alberta	1089500	126694302.99601549
7	Alberta	1956	3.17	36.7	-40.0	136	Alberta	1122250	126031332.03062077
8	Alberta	1957	2.95	36.7	-38.3	125	Alberta	1161250	126031332.03062077
9	Alberta	1958	3.84	36.7	-35.0	127	Alberta	1205250	125542390.0193746
10	Alberta	1959	2.68	36.7	-37.3	122	Alberta	1247250	125984305.8945365
11	Alberta	1960	2.99	40.6	-38.3	119	Alberta	1289750	126545978.99966139
12	Alberta	1961	3.86	41.7	-37.8	123	Alberta	1330500	126236942.82300198
13	Alberta	1962	4.83	36.1	-35.6	180	Alberta	1368500	123991452.6280004
14	Alberta	1963	5.6	37.2	-35.0	201	Alberta	1402500	124504007.49060571
15	Alberta	1964	4.45	38.9	-35.6	208	Alberta	1427750	126194719.84738185
16	Alberta	1965	4.32	35.6	-37.8	279	Alberta	1448000	118086067.04416536

6.Weather API & Front-end development

Front-end Development: To display real-time weather data across major Canadian provinces, the front-end of the platform was developed using React. The application integrates a weather API (supporting both JSON and XML formats) that provides live weather information based on geolocation or user-selected regions. This setup allows users to view up-to-date temperature and weather conditions, enhancing the platform's interactivity and relevance to ongoing climate discussions.

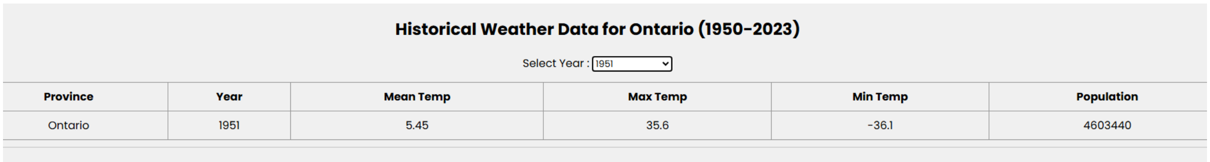


WeatherAPI

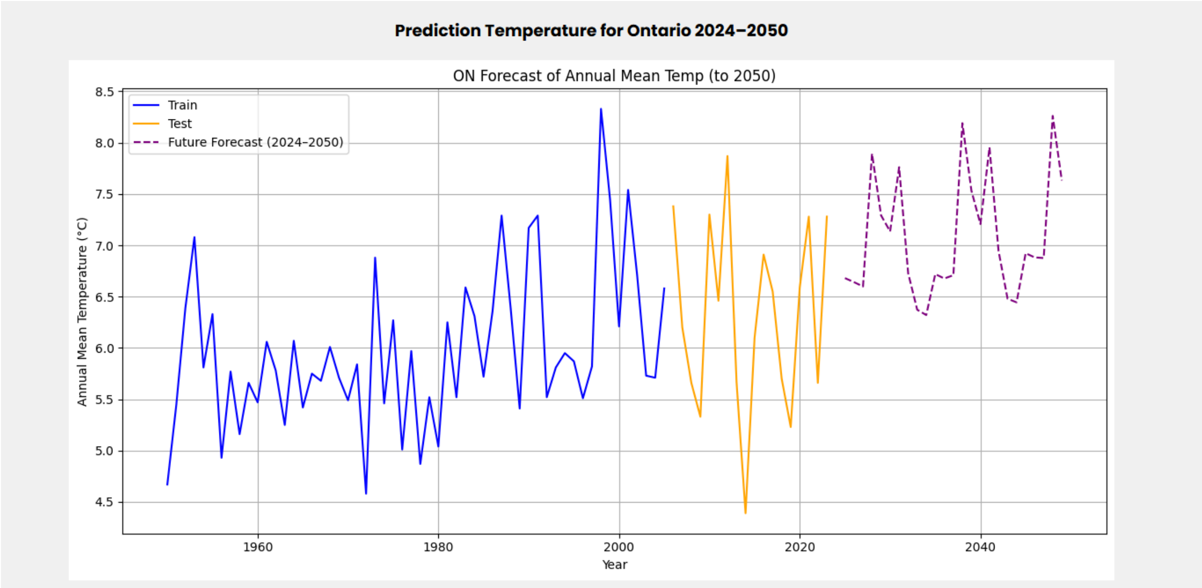
Website layout

1). Weather API provides both real-time weather conditions and a 7-day forecast for major cities across Canadian provinces. Users can interact with a simple interface to select a city from key provinces and instantly view localized climate information.

2). The platform also offers historical climate and population data from 1950 to 2023, based on user input. Users can select a specific year and view detailed information such as maximum, minimum, and mean temperatures, as well as the province's population. This feature allows users to explore long-term trends and gain deeper insight into climate and demographic changes over time.



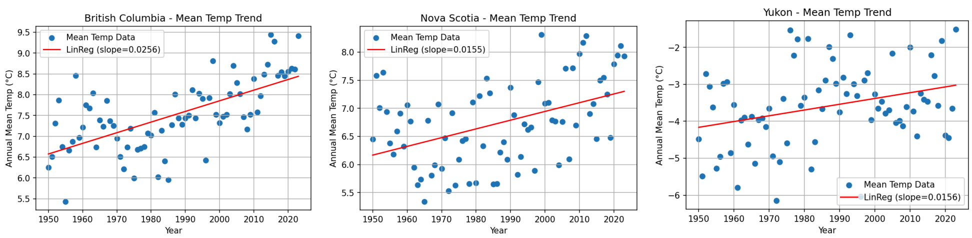
3). The last section of the platform focuses on future climate prediction, allowing users to input a province and generate forecasted mean temperatures from 2024 to 2050. This prediction is based on historical trends and machine learning models (Arima model), offering insights into potential long-term climate changes in each region.



7.Analysis

(1) Trends in annual mean temperature - classify into three categories

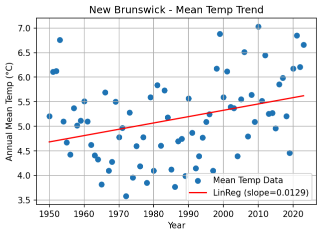
A. High Warming Trend (Slope > 0.015)

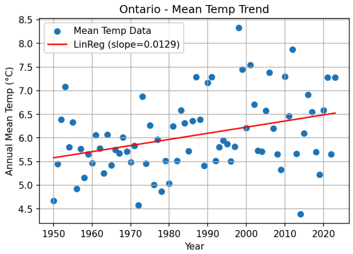
- British Columbia (0.0256): Shows the most significant increase in mean temperature. The upward trend is clear and steady, indicating substantial warming over the past 70 years.
- Yukon (0.0156): Despite colder baseline temperatures, Yukon shows a marked warming trend due to Arctic amplification.
- Nova Scotia (0.0155): The maritime province has also experienced noticeable warming, possibly driven by changes in ocean currents and regional humidity.
- 

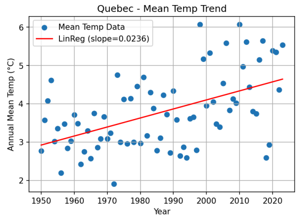
B. Moderate Warming Trend (0.01 ≤ Slope ≤ 0.015)

- Ontario (0.0129) and New Brunswick (0.0129): Both central and eastern provinces show a moderate warming pattern with relatively stable data distribution.

- Quebec (0.0236): Though technically in the high range, Quebec has more variance but still shows an overall warming trend.

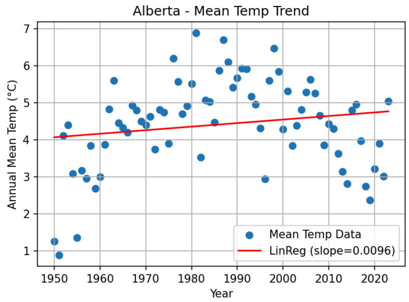


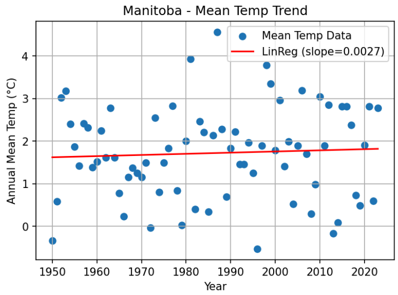


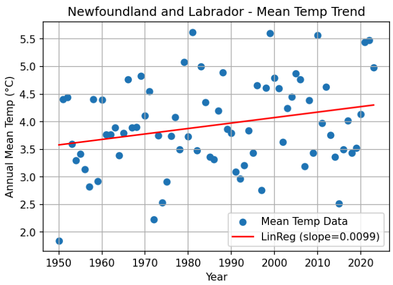


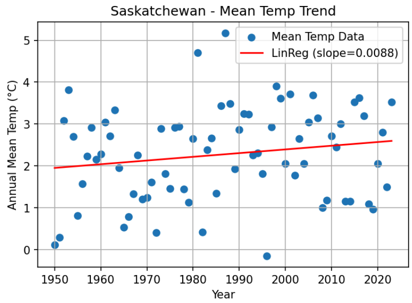
C. Low Warming Trend (Slope < 0.01)

- Alberta (0.0096), Saskatchewan (0.0088), Newfoundland and Labrador (0.0099), and Manitoba (0.0027): These provinces exhibit slight upward trends in temperature, with more variability and slower change.









D. Observations & Conclusions

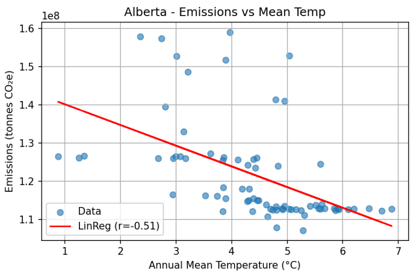
- Western provinces like British Columbia and northern regions such as Yukon are warming faster than inland Prairie provinces.
- The linear regression lines show that while some regions have erratic yearly data, overall temperature increase is evident across all provinces.

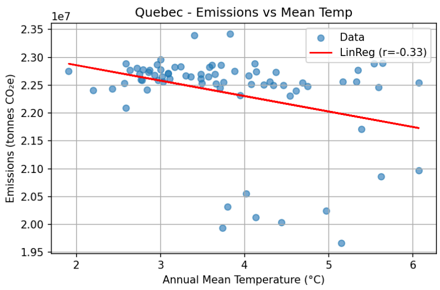
(2) Emissions vs. Temperature Analysis by Province

This section analyzes the correlation between annual mean temperature and total emissions across ten Canadian provinces, using linear regression and Pearson correlation coefficient (r) to quantify the relationships.

A. Strong Negative Correlation

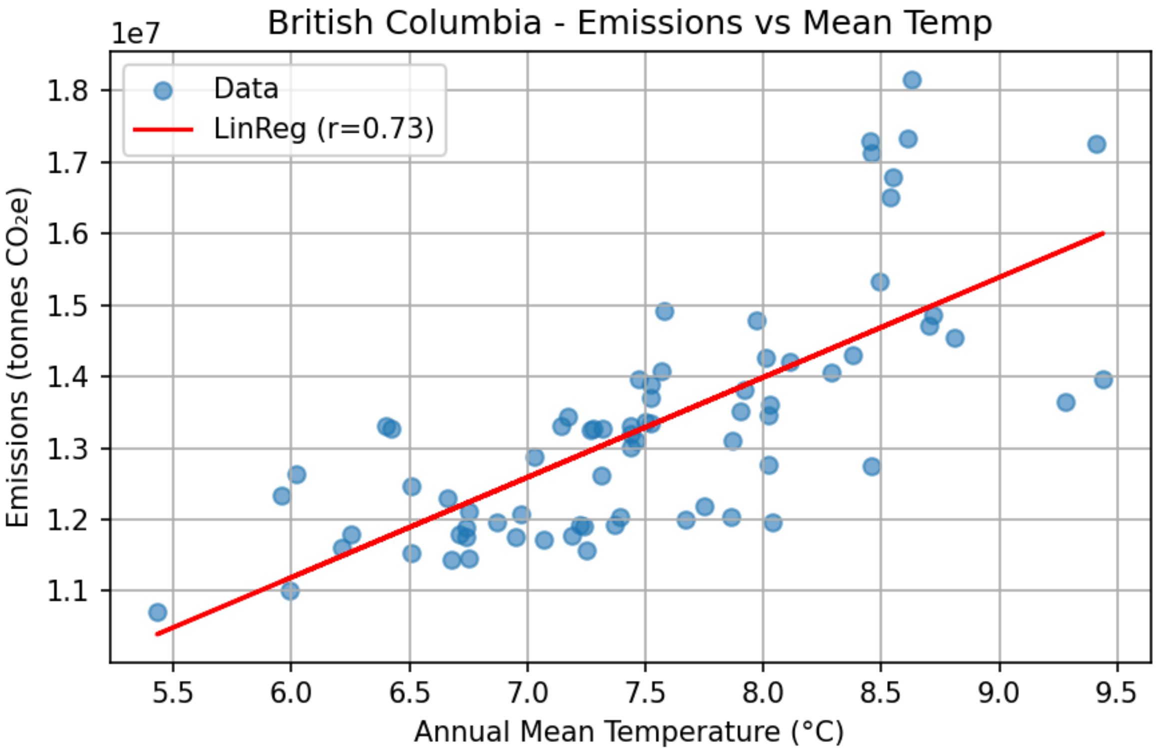
- Alberta (r = -0.51): Alberta shows a strong negative correlation, indicating that as temperature increases, emissions tend to decrease significantly. This could reflect climate-driven shifts in industrial or energy demands, or policy impacts.
- Quebec (r = -0.33): Similar to Alberta, Quebec's data suggest that warmer years correlate with slightly reduced emissions, possibly due to increased hydroelectric use or efficiency improvements in warmer periods.





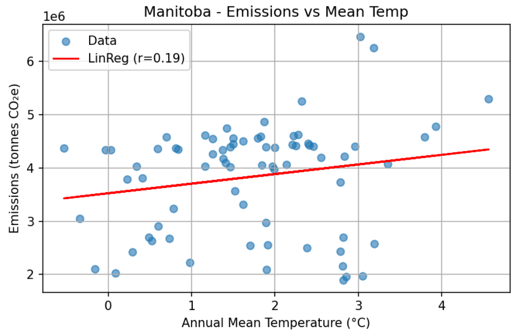
B. Strong Positive Correlation

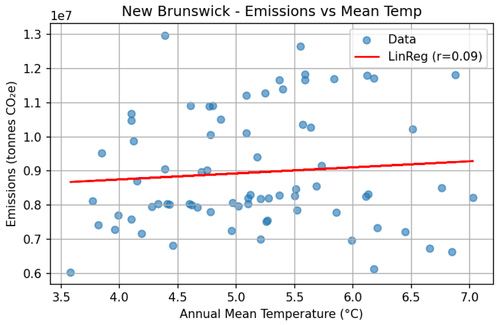
- British Columbia (r = 0.73): This province displays a strong positive correlation. Higher temperatures correspond with increased emissions. This may be due to greater energy consumption (e.g., air conditioning), population growth, or industrial expansion during warmer years.

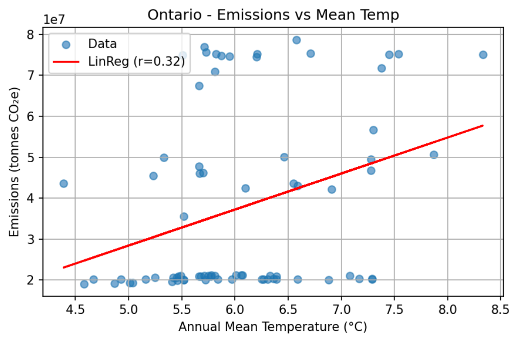


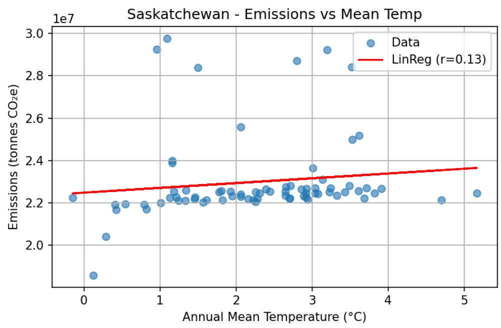
C. Moderate Positive Correlation

- Ontario (r = 0.32): Ontario demonstrates a moderate positive relationship, suggesting a rising trend in emissions alongside warming. This may be influenced by both urbanization and energy demand trends.
- Manitoba (r = 0.19): Manitoba shows a weak-to-moderate positive trend. While not conclusive, the data hint that warmer years may slightly raise emissions.
- Saskatchewan (r = 0.13): This weak positive correlation shows limited sensitivity of emissions to temperature changes, suggesting other dominant drivers such as industrial output.
- New Brunswick (r = 0.09) and Yukon (r = 0.06): Both show very weak positive relationships, implying minimal temperature impact on emissions trends.



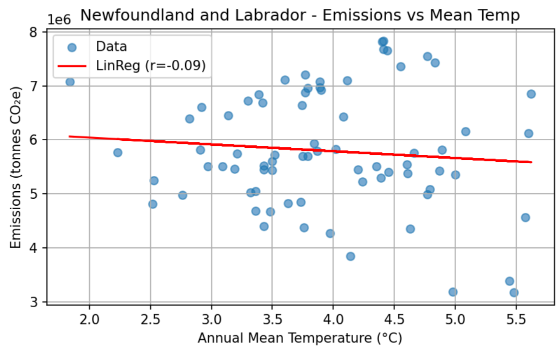


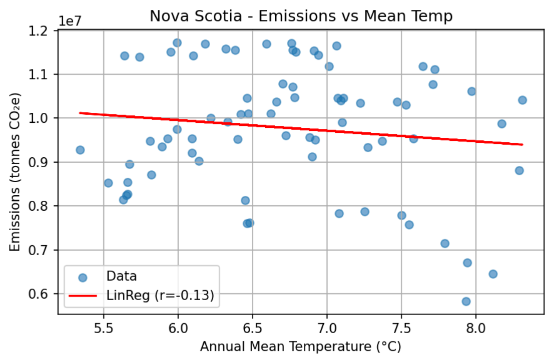




D. Weak Negative Correlation

- Nova Scotia (r = -0.13) and Newfoundland and Labrador (r = -0.09): Both provinces show slight negative correlations, indicating modest reductions in emissions as temperatures rise. This may result from energy mix changes or demographic factors.





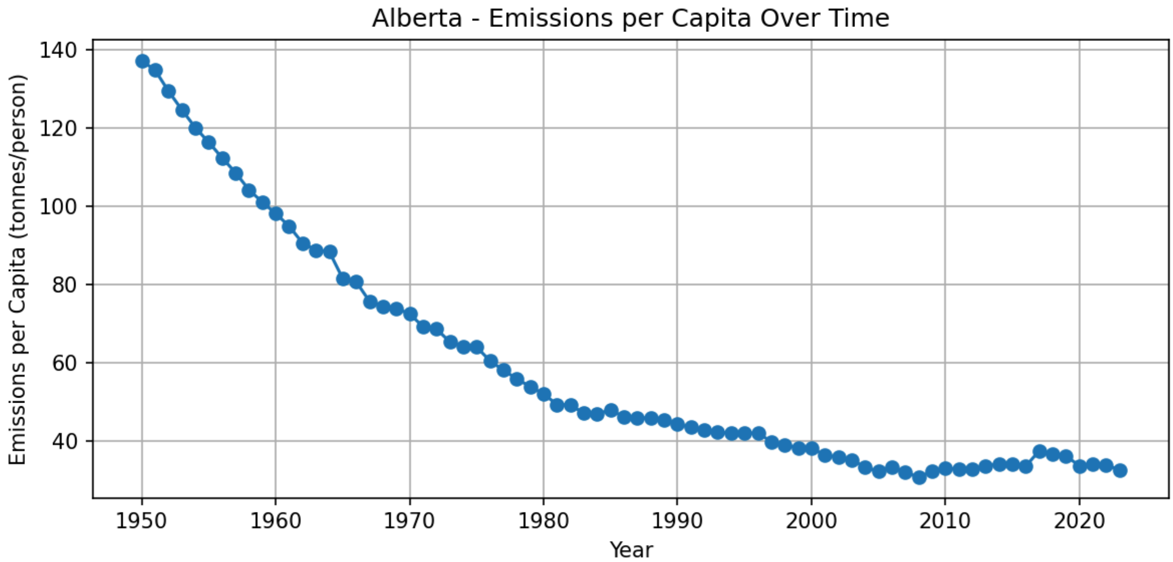
Summary

These results highlight varied regional responses to temperature changes. Western provinces like Alberta and Quebec are reducing emissions as temperatures rise, possibly due to cleaner energy use or regulatory efforts. In contrast, British Columbia and Ontario show rising emissions with temperature, suggesting growth-driven or climate-sensitive demand. Other provinces display more neutral patterns, indicating complex and multifactorial relationships that warrant deeper study.

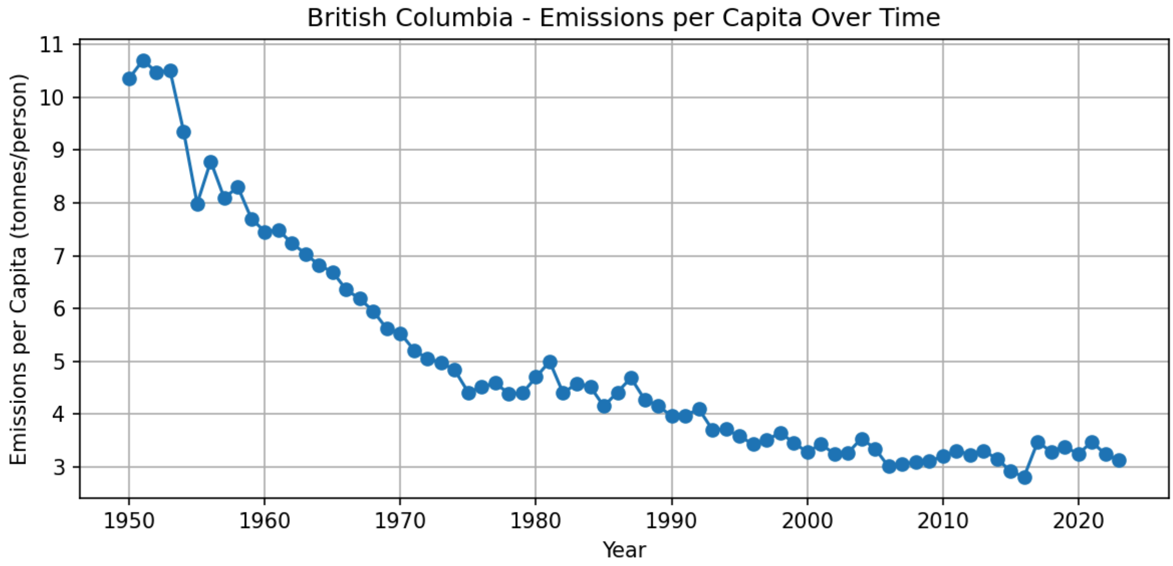
(3). Emissions per Capita Trends Across Canadian Provinces (1950-2023)

This analysis examines per capita greenhouse gas (GHG) emissions from 1950 to 2023 across ten Canadian provinces, aiming to evaluate long-term environmental efficiency and climate-related policy impacts at the individual level.

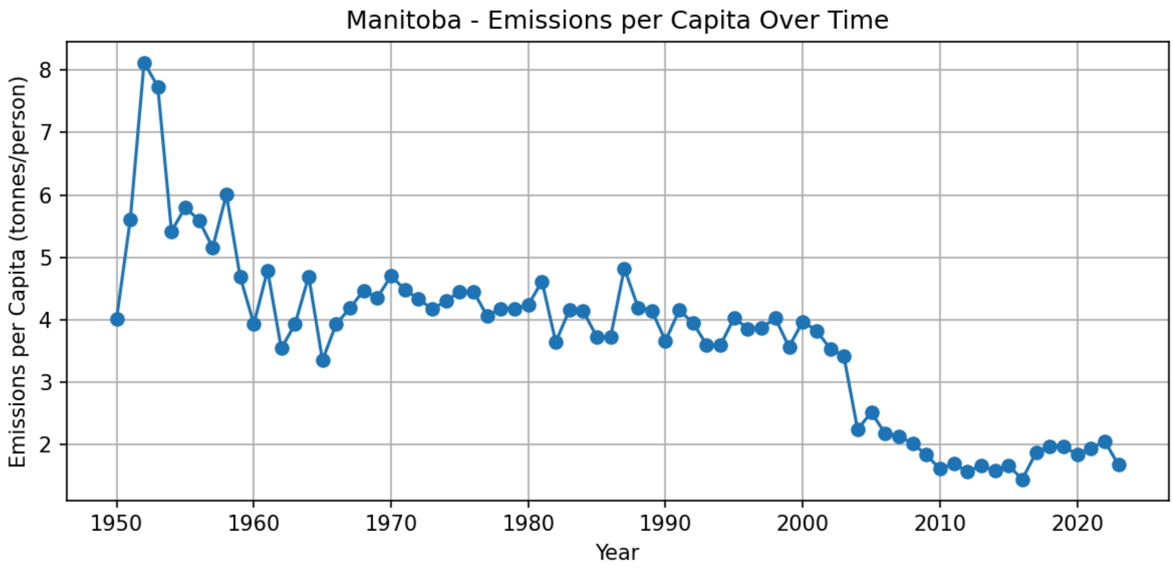
Alberta: Alberta consistently recorded the highest per capita emissions historically, peaking above 130 tonnes per person in 1950. However, the trend demonstrates a steep decline over the decades, reaching about 33 tonnes by 2023. This sharp drop reflects population growth and industrial efficiency improvements despite Alberta’s continued reliance on fossil fuel industries.



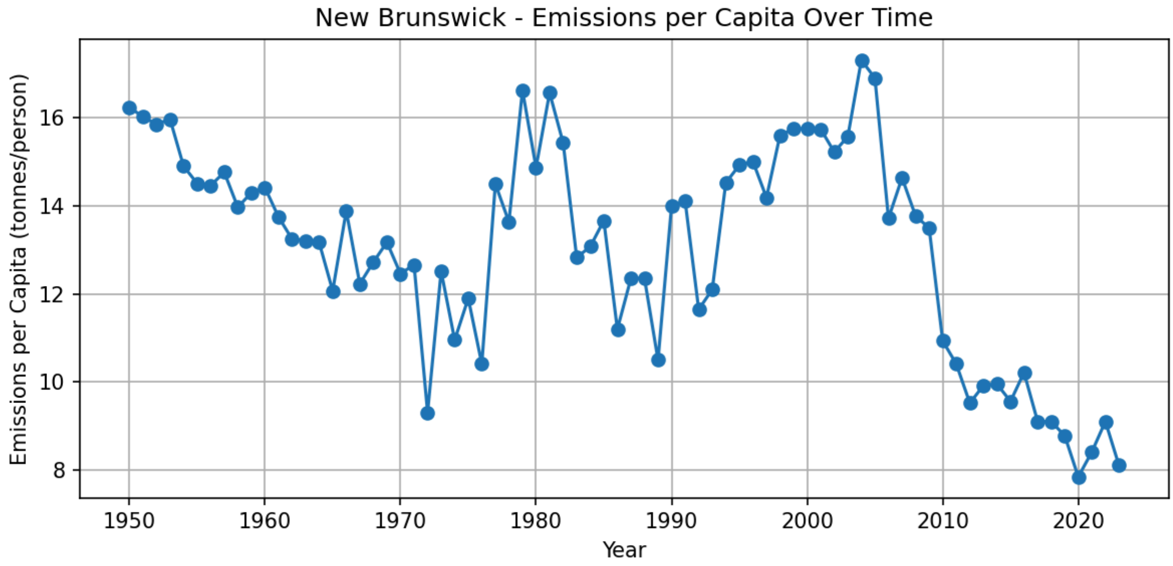
British Columbia: Emissions per capita decreased steadily from about 10 tonnes in 1950 to around 3 tonnes in recent years. This long-term downward trend highlights British Columbia's shift toward greener energy and effective climate policy.



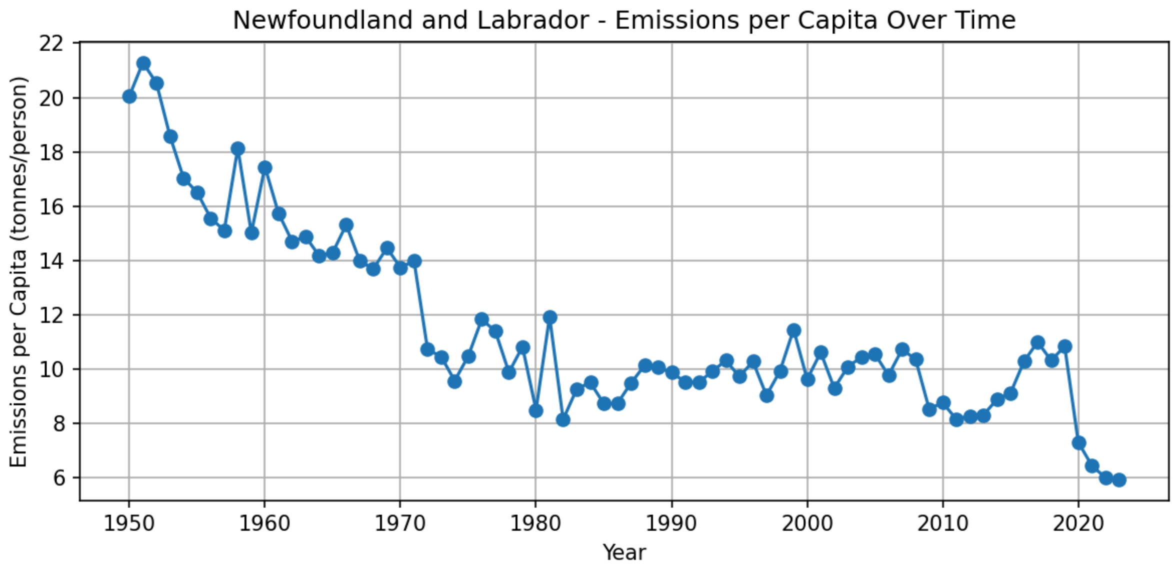
Manitoba: Manitoba's per capita emissions were moderate and relatively stable over time, declining from 8 tonnes in the early 1950s to below 2 tonnes by 2023. The stable, gradual decrease suggests a consistent transition towards lower-emission practices.



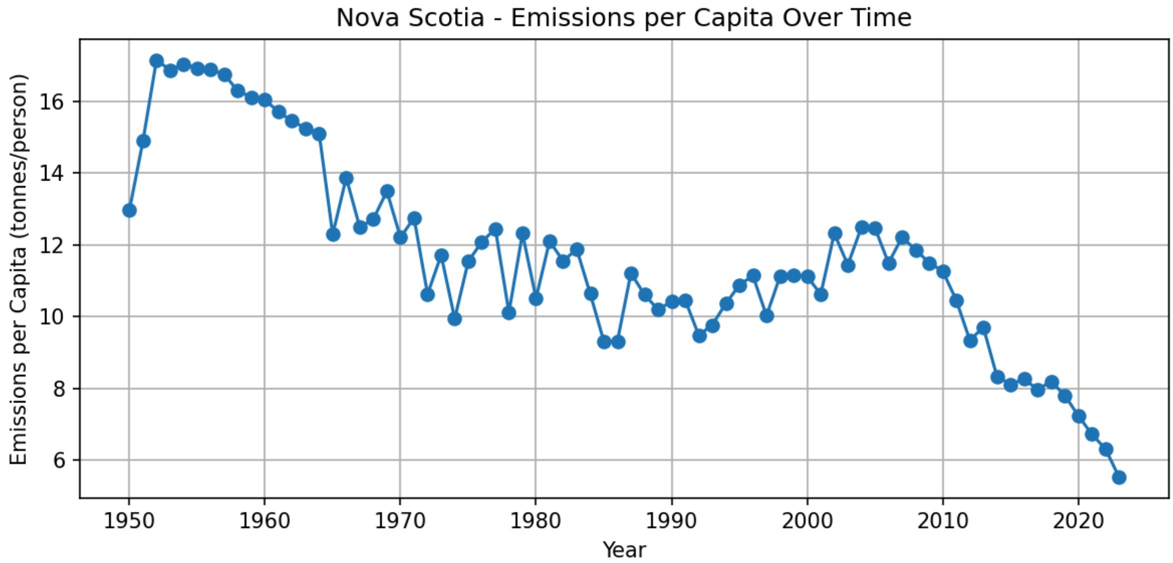
New Brunswick: Per capita emissions exhibited volatility, peaking between 15–17 tonnes in the 1990s and early 2000s before decreasing significantly to around 8 tonnes by 2023. The fluctuation may be attributed to changes in industrial output and energy sourcing.



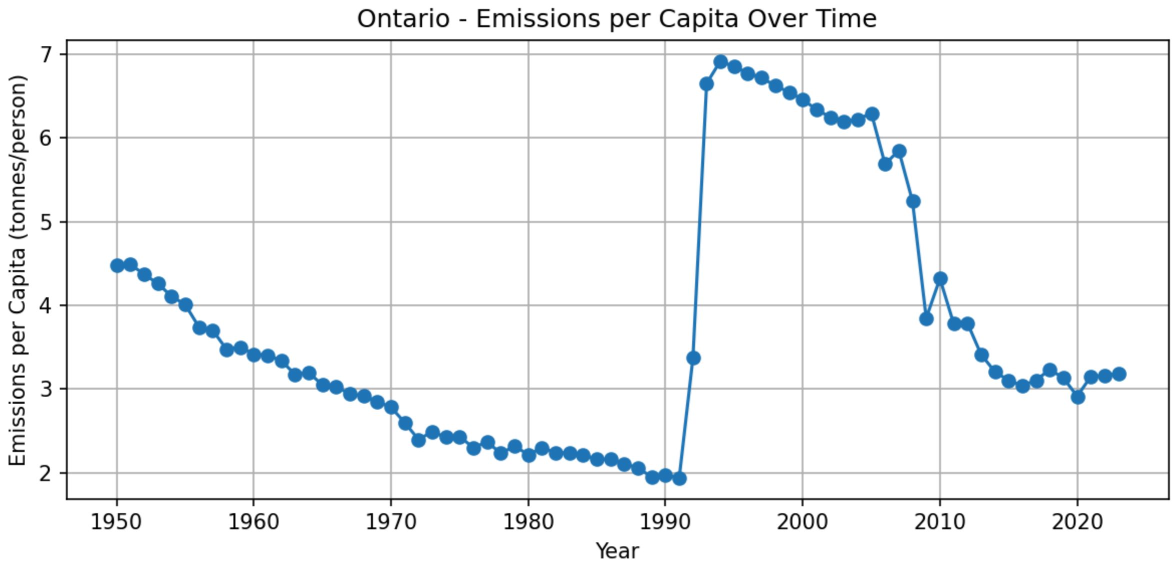
Newfoundland and Labrador: Emissions per capita dropped from over 20 tonnes in the 1950s to approximately 6 tonnes in 2023. The declining trend reflects industrial modernization and possibly population growth effects in balancing emissions.



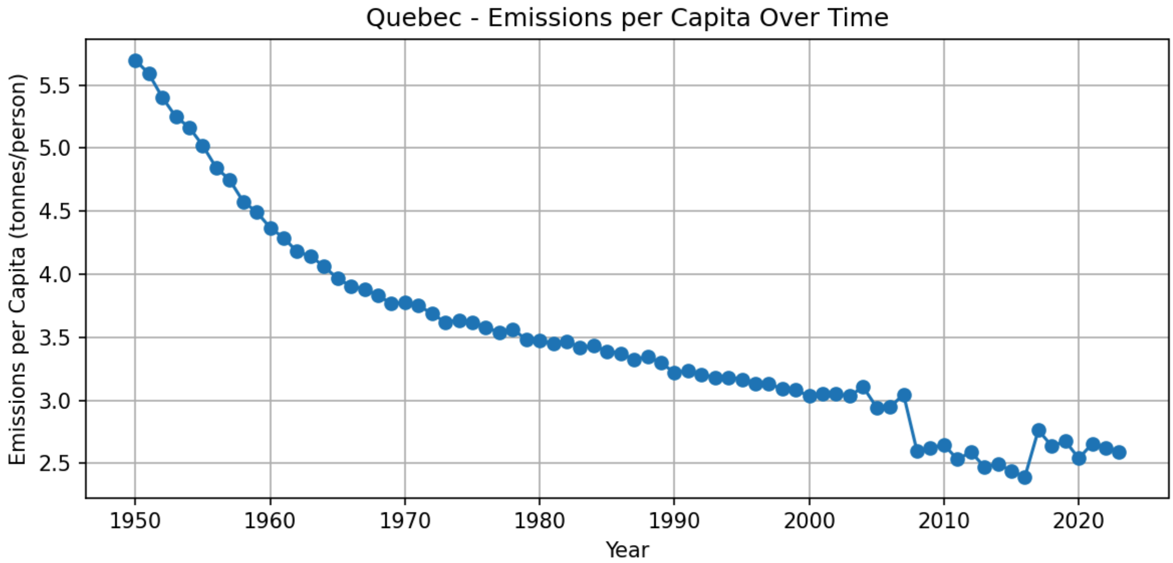
Nova Scotia: Similar to New Brunswick, Nova Scotia showed high per capita emissions until the early 2000s, followed by a noticeable reduction to around 6 tonnes. The late but steep drop suggests recent policy action or shifts in energy infrastructure.



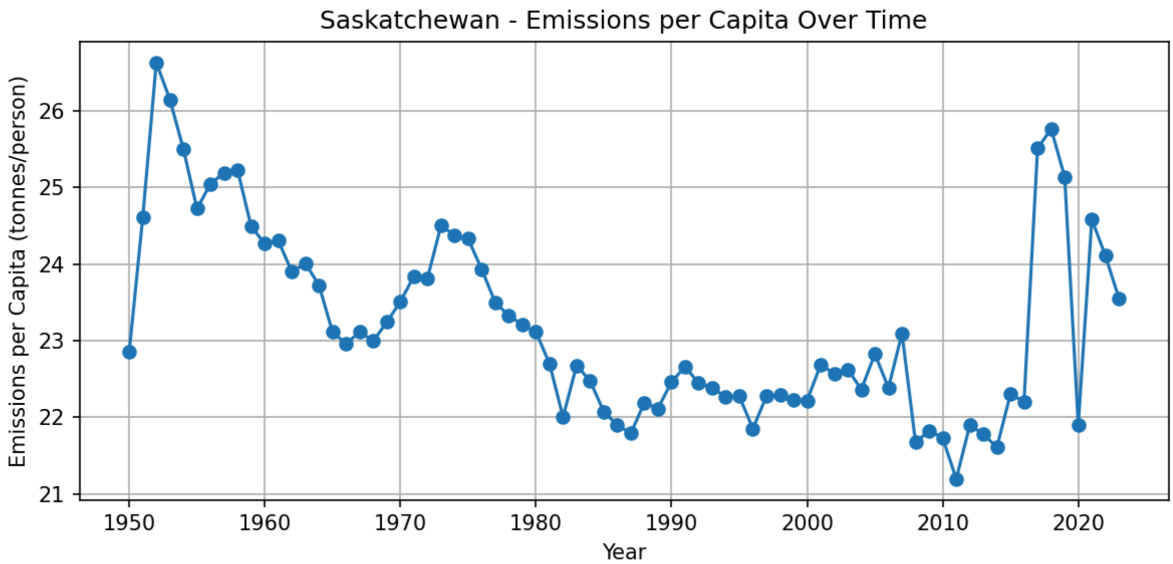
Ontario: Ontario began with relatively low per capita emissions and maintained a downward trajectory. Anomalous spikes occurred in the 1990s and early 2000s, reaching up to 6.9 tonnes, likely due to energy generation factors. By 2023, emissions returned to around 3.2 tonnes.



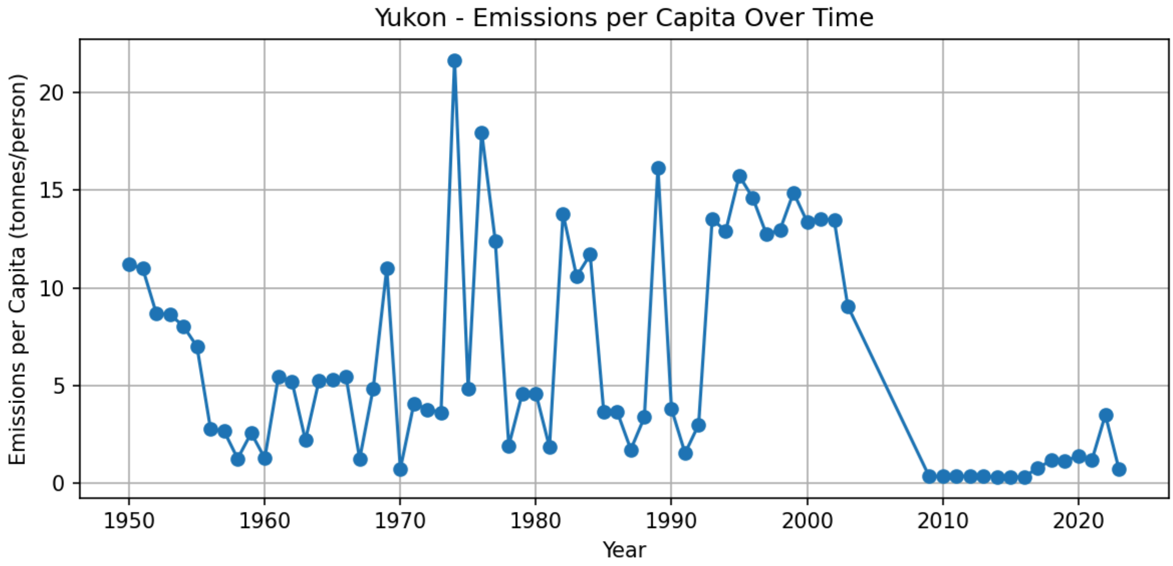
Quebec: A steady decline in per capita emissions is observed, dropping from about 5.5 tonnes to around 2.5 tonnes over 70 years. Quebec’s reliance on hydroelectric power and proactive policies appear to underpin this reduction.



Saskatchewan: Saskatchewan maintains consistently high per capita emissions, hovering around 22–26 tonnes throughout the timeline, with recent years showing slight declines. This persistence signals limited progress in decarbonizing industrial or energy systems.

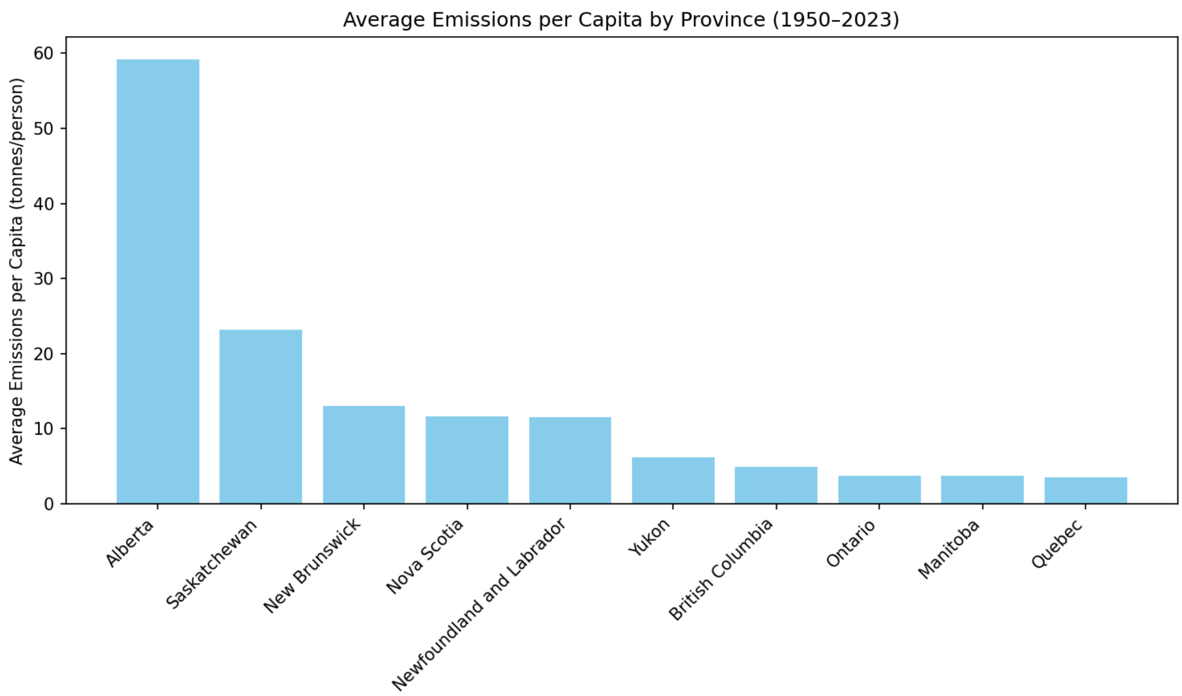


Yukon: Yukon’s per capita emissions are highly erratic, reflecting its small, fluctuating population and variable industrial activity. Peaks exceeding 20 tonnes contrast with years nearing zero, suggesting that emissions here are highly sensitive to isolated economic events.



Conclusion: Most provinces show a declining trend in per capita emissions, albeit with varying steepness and stability. The differences reflect regional energy sources, industrial profiles, and climate policy effectiveness. Alberta and Saskatchewan remain outliers with persistently high values, while provinces like Quebec and British Columbia demonstrate successful emission control over time.

(4). Average Emissions per Capita by Province (1950–2023)



The bar chart visualizes the average emissions per capita across Canadian provinces from 1950 to 2023. Alberta stands out significantly, with the highest average emissions per person—nearly 60 tonnes—surpassing all other provinces by a wide margin. This aligns with Alberta’s heavy reliance on fossil fuel industries, particularly oil sands extraction. Saskatchewan follows as a distant second with approximately 23 tonnes per capita.

A middle tier includes New Brunswick, Nova Scotia, and Newfoundland and Labrador, averaging between 11–13 tonnes per person, reflecting more modest industrial activity and energy demands. On the lower end, provinces such as British Columbia, Ontario, Manitoba, and Quebec maintain much lower per capita emissions, ranging from 3–5 tonnes. Quebec notably records the lowest among all, which is consistent with its long-standing investment in hydroelectric power.

This comparison underscores the regional disparity in carbon intensity and energy reliance, highlighting Alberta and Saskatchewan as outliers in Canada's carbon emissions landscape.

8. Conclusion

This project reveals a complex, yet deeply interconnected portrait of Canada’s climate and emissions landscape. When evaluating temperature trends, emissions totals, emissions per capita, and their correlations together, clear structural patterns emerge that transcend individual metrics.

Provinces with the **highest emissions per capita**, such as **Alberta and Saskatchewan**, not only maintain the most carbon-intensive profiles but also show **relatively low or even negative correlation** between emissions and temperature. This suggests that even as their local climate warms, emissions are not increasing in tandem — likely due to population growth diluting per-person metrics or late-stage industrial policy interventions that haven't yet affected historical warming.

In contrast, provinces like **British Columbia and Ontario** demonstrate **moderate to high positive correlations** between emissions and temperature, while maintaining **moderate or low per capita emissions**. This indicates a strong coupling between human activity and local climate, but also reflects the tension between **economic growth and emissions control**.

These regions are urbanizing, but still managing to improve emissions efficiency.

Quebec stands out as a model of environmental resilience: it has **one of the lowest per capita emissions**, a **steady decrease over time**, and a **negative correlation** between temperature and emissions. This triple alignment suggests that early investment in hydroelectricity and consistent climate policy have successfully decoupled economic growth from environmental degradation — a blueprint for sustainable development.

Regions like **Yukon and Manitoba**, with minimal correlations and erratic or flat trends, highlight how **climate variability and small populations** can obscure clearer patterns. These areas may require more targeted data collection or region-specific strategies that account for their unique scale and sensitivity.

Ultimately, when these four analytical lenses are combined, we see that Canada's provinces fall into distinct climate-efficiency profiles:

- **High emitters with weak climate-emissions alignment** (e.g., Alberta, Saskatchewan)
- **Moderate emitters with strong alignment** (e.g., B.C., Ontario)
- **Low emitters with evidence of decoupling** (e.g., Quebec)
- **Unstable or ambiguous cases needing deeper study** (e.g., Yukon, Manitoba)

This integrated view reinforces a key conclusion: **climate change is experienced and driven differently across regions**. National climate policy must be adaptive — not uniform — and account for these multidimensional provincial profiles if it aims to be both fair and effective.

Why Climate Policy Is Still Needed

One of the key findings of this project is that in some provinces, such as Alberta and Quebec, emissions have been decreasing over time, yet temperatures continue to rise. This apparent disconnect highlights an important reality: the climate system responds slowly to change due to the long-lasting impact of greenhouse gases already in the atmosphere.

Even with recent emission reductions, the planet — and each region — is still feeling the effects of decades of accumulated emissions. This is known as climate inertia. Without sustained and aggressive policy action, warming will continue, and any short-term reductions will not be enough to reverse long-term trends.

This is precisely why climate policy is essential:

- To accelerate emissions reductions and reach net-zero faster
- To prepare regions for ongoing warming that is already locked in
- To coordinate long-term adaptation strategies (e.g., infrastructure, agriculture, water resources)
- And to avoid backsliding, ensuring reductions are consistent and verifiable