Research Article

Does US States' GDP Influence Consumers' Preferences for Renewable Energy?: A Preliminary Analysis of Twitter Posts

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Abstract
State-led renewable energy support is on the rise, and demand for renewable energy-based related products is growing. Positive consumer sentiment towards renewable energy can support qualitative growth. Additionally, it can be used to develop marketing strategies to increase sales of renewable energy and related products. A deeper understanding of how local income levels influence preference for renewable energy is one step in this direction. In the present study, tweets were mined from Twitter in various regions to analyze the public sentiment about renewable energy in different regions of the United States. Tweets were classified based on various renewable energy sources such as solar power, wind power, and tidal power. An analysis of tweets collected from January 1, 2017 to January 15, 2022 revealed that public sentiment varied from state to state. Furthermore, regional income levels highly correlated with preference for renewable energy and related products. Future research on factors influencing this association could inform government-led promotion strategies to improve the sales of new and renewable energy products.
Keywords: Renewable Energy, Income, Regional Trends, Twitter, Consumer Sentiment.

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Introduction

The renewable energy industry and related technology development have exhibited a strong and rapid growth in recent years. The global energy market is shifting towards renewables, focusing on solar and wind power. Energy has been regarded as a means for national development and maintenance, but environmental worries are gradually emerging. Hence, efforts to secure and maintain inexpensive and high-quality energy resources are moving towards more consideration of environmental factors for sustaining development. According to a study conducted by International Renewable Energy Agency (IRENA), renewable energy is frequently cheaper than fossil fuel alternatives, employs over 11 million people worldwide, and reduces negative environmental impacts. The clear economic and environmental benefits of renewable energy is an excellent way to close political divides on issues related to energy, climate change, and sustainability.

Accordingly, the governments of several countries are making efforts to promote new and renewable energy policies and to aid the market for such products. These policies can be divided into three types: Renewable Energy Standards (RPS), the imposition of taxes such as carbon taxes and the provision of relative incentives, and the creation of a carbon market through cap-and-trade restrictions (Vad, *et al.,* 2015). These government subsidies and purchase incentives aimed at preventing environmental pollution and climate change are stimulating consumers' interest in purchasing EVs and solar power generation devices.

Since the late 1990s, several US states have established renewable energy policies such as Renewable Portfolio Standards and those related to the sale of environment-friendly products, disclose waste management and carbon emissions, and provision of subsidies for companies' green practices (Menz and Vachon, 2006; Izadian, *et al.,* 2013). According to Delmas and Montes-Sancho (2011), state policies related to renewable energy mainly pertain to the provision of incentives or to setting clear guidelines and regulations on climate action, including mandatory disclosure rules. For instance, several US states offer income tax credits for investing in the production and utilization of green electricity (Menz, 2005).

According to the US Energy Information Administration, the following states were the top ten producers of renewable energy (measured in million megawatt-hours) in the US in the first quarter of 2022: Texas, Washington, California, Lowa, Oregon, Oklahoma, New York, Kansas, Illinois, and Minnesota (Gilligan, 2022). For a more holistic view of states' performance on achieving renewable

energy goals SmartAsset compared 50 states based on seven metrics, including renewable energy production, per capita carbon emissions, and state funding for renewable energy. Their findings showed that North Carolina topped the list, followed by California, Massachusetts, Vermont, and Arizona in the top 5 (Villanova, 2022).

The vast variation in states' policies and extent of success in meeting renewable energy goals is clear. According to Vasseur (2014), several economic and political factors influence these outcomes. One of the primary economic factors is the state's income. Specifically, states with higher GDP have been confirmed to be more likely to adopt renewable energy policies, partially because they have more resources to implement these regulations (Daley and Garand, 2005; Vachon and Menz, 2006). Several studies have found that a state's GDP is positively correlated with its renewable energy generation (Carley, 2009; Burke, 2010) and a bidirectional causality between a state's renewable energy consumption and GDP has been reported (Sadorsky, 2009; Apergis and Payne, 2010, 2011, 2012).

This brings us to the question of whether and how this income factor trickles down to the consumer level. Findings in this regard point to different mechanisms. Sodorsky (2011) suggested that the increased access to financial resources in a state caused by its financial development leads to an increase in energy usage via the increased consumption of durable consumer goods. Specifically, with increased disposable income and easier borrowing, consumers are more likely to spend on expensive consumer goods that consume more energy. However, Islam *et al.,* (2013) argue that financial development facilitates the purchase of energy-efficient appliances, which lowers energy use. Substantial research supports the link between income and readiness to spend more on renewable energy or related products (Bollino, 2009; Oliver, *et al.,* 2011; Ohler, 2015).

Other than access to disposable income or readiness to spend on renewable energy products, the public's social acceptance and beliefs in the concept influence the success of efforts and policies to increase the utilization of renewable energy products (Heras-Saizarbitoria, *et al.,* 2013; Smith and Leiserowitz, 2014; Tabi and Wustenhagen, 2017). While individual factors such as education, age, political affiliation (Sardianou and Genoudi, 2013; Hamilton, *et al.,* 2019), and belief in concepts such as global warming and climate change (Noblet, *et al.,* 2015; Dreyer, *et al.,* 2017) influence people's opinions about renewable energy, the contribution of renewable energy to the local economy also garners public support for such policies (Bidwell, 2013; Olson-Hazboun, *et al.,* 2016). According to Dasgupta, *et al.,* (2002), one of the reasons for this could be that, as income increases, individuals begin to place higher value on factors related to their living environment, such as drinking water, clean air, etc. This environmental consciousness in turn encourages them to consider the use of renewable energy to protect the environment.

Considering these trends, the present study aimed to examine if the macro-level factor of state GDP was associated with the micro-level factor of consumer sentiments toward renewable energy. Although many studies have examined views on specific energy technologies at the national and regional levels (Pahle, *et al.,* 2016), it is difficult to observe immediate or recent public opinions related to renewable energy. Additionally, it is extremely difficult to grasp the fluctuating public opinion because it changes based on the current social atmosphere (Schmalensee, 2012). To address these limitations, several approaches using big data analytics are being used. Social media is an extremely sought-after source of information, both in academia and industry, for observing public perception. Deviating from the existing survey method, social networking sites (SNSs) such as Twitter and Instagram can examine the interests and reactions of users (Sun, *et al.,* 2019). This makes it relatively easy for academic researchers and public officials to investigate public opinion on local and national energy policies and plans using SNS, and find sentiment on a broader scale (Bertsch, *et al.,* 2016).

The present study analyzed the general public's interest and sentiment toward renewable energy through texts posted on Twitter. Consumers' tweets are reflective of their experience in using derivatives related to renewable energy as well as their interest in and responses to information about subsidy programs that can be obtained at the time of purchase. Advanced statistical techniques using Natural Language Processing (NLP) and Machine Learning (ML) allow us to analyze these public interests and to examine their association with related factors. It was hypothesized that the general income level of each state would correlate to interest and positive sentiment towards renewable energy.

Materials and Methods

Social media analytics is increasingly being used to identify data patterns that can inform policy-making and business strategies (Fan and Gordon, 2014). With quick and easy access to immense amounts of data extracted from posts created by social media users provides, this emerging field of social research offers opportunities to measure consumer perceptions and attitudes (Zikopoulos, *et al.,* 2012). Among the variety of social media platforms available, Twitter has become a popular medium among researchers because not only can users posts can be subjected to text analysis, but their background information can be used to examine associations with other influencing factors (Ibrahim and Wang, 2019).

In the present study, data were collected via the Twitter API from January 1, 2017 to January 15, 2022. Collection keywords were limited to post texts containing renewable or #renewable. Additional conditions were that the tweets were in English, retweets were discarded, and tweets provided geographical information. Python was utilized to perform data analysis and data visualization.

To further understand the nature of users' posts, sentiment analysis was used. Specifically, sentiment analysis can be used to examine subjective text, which relate to the affective aspects of people's opinions (Liu, 2010). As sentiment analysis often involves the assessment of the polarity of emotions expressed, it is widely used by marketing professionals to evaluate customers' social media opinions towards products and services (Thelwall, 2018; Zhang, *et al.,* 2022). Essentially, this method uses algorithms to classify the underlying sentiment in the social media post as positive or negative (Zhang, *et al.,* 2022).

PyTorch was implemented as the deep learning framework. For sentiment analysis, DeBerta V3, a pre-trained model, which was released in November 2021, was used. DeBerta V3 was pre-trained on a wide range of subjects and large datasets and has shown good performance. With this model, the tweets' sentiment towards renewable energy was classified binarily: positive or negative. Following this classification, the distribution of positive and negative tweets was analyzed by the GDP of each state in the US.

Results and Discussion

The results of analysis have been presented in Figure 1 and 2. Figure 1 shows the GDP of each US state as of 2020. In ascending order, the top 5 states in terms of GDP were add names.

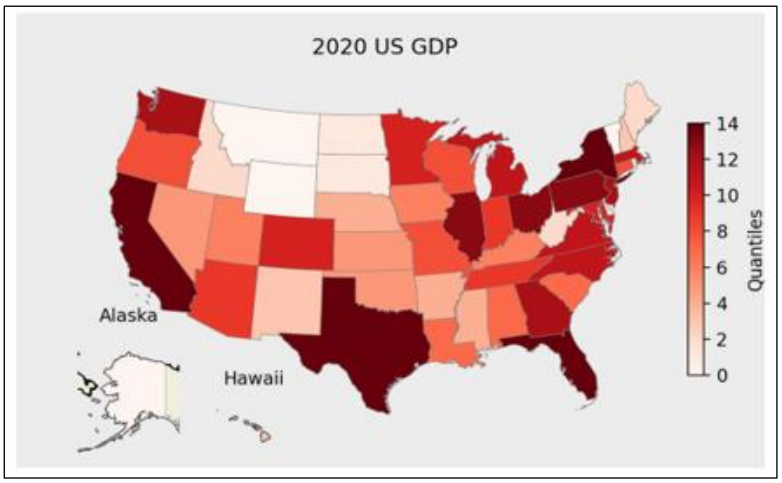

Figure 1. US states' 2020 GDP

Figure 2 shows the state-wise distribution of the number of positive tweets related to renewable energy collected from Twitter during the study period. The top 5 states, in ascending order, were: add names.

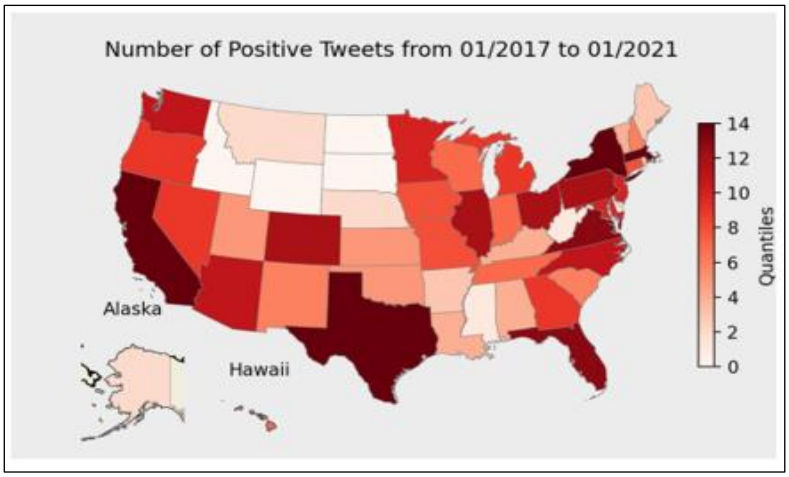

Figure 2. State-wise distribution of positive tweets about renewable energy from January 2017–2021

On comparing the two figures, it is evident that the proportion of positive tweets about renewable energy tended to be higher in regions with high GDP, suggesting that consumers in these states were more likely to have positive sentiments toward renewable energy. Geographical characteristics can cause differences in the livelihoods, incomes, and cultures of local residents, which may in turn influence their opinions about various topics, including those on renewable energy.

Furthermore, considering a recent report of top five producers of renewable energy (Texas, Washington, California, Lowa, and Oregon) (Gilligan, 2022), the present findings suggest a close link between a state's production and utilization of renewable energy, its GDP, and consumers' positive opinions. It would be interesting to further compare these findings based on other factors such as political affiliation, the state's primary source of income, extent of manufacturing, energy policies, etc., to gain a deeper understanding of their influence on consumer sentiments.

To further examine if consumers' positive opinions about renewable energy translated to the actual consumption of related products, the 2020 sales of electric vehicles was examined. As evident from Figure 3, which presents distribution of electric vehicles registered in 2020 in different metropolitan areas across the US.

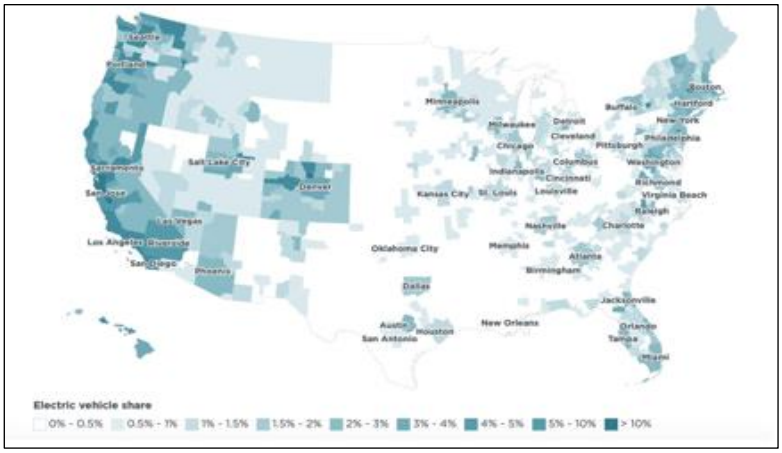

Figure 3. Electric vehicles registered in 2020 in different metropolitan areas across the US

Interestingly, the trends are similar to those observed in Figure 1 and 2 except for Texas. This finding corroborates the close association between income and readiness to spend more on renewable energy or related products (Bollino, 2009; Oliver, *et al.,* 2011; Ohler, 2015) as well as other mechanisms of influence explained in the Introduction section.

Conclusion

In this research, the results of analyzing public sentiment on renewable energy through machine learning and NLP on social media posts revealed that the GDP of each US state was positively correlated with positive sentiments toward related products. In other words, consumers from high-income states in the US expressed more positive sentiments toward renewable energy products. This positive sentiment was also reflected in their actual consumption of such products, as

evidenced by similar state-wise trends in the purchase of electric vehicles during the reference period. A key factor that may have contributed to these trends is that the respective governments' implementation of renewable energy policies and the related economic development may have led to ripple effects on the positive experiences and responses of consumers. It is likely that, in high income level regions, people were able to directly purchase solar power, electric vehicles, and derivatives, and after purchase, they tended to share their positive experiences through social media. However, it is important to consider the limitations of this study when interpreting the present findings.

One important aspect is that consumer sentiments, especially on a contentious issue such as renewable energy, are influenced by several socio-political factors. However, this study only examined the association with state GDP. Though the present study is a preliminary analysis of the data extracted from Twitter, it shows the potential for using social media to gain deeper insight into the public's attitude towards topics. This understanding can then be utilized to develop appropriate policies and awareness building measures to garner public support for novel energy programs and products.

Conflicts of interest: The authors declare no conflicts of interest.

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