Financial Modeling of Renewable Energy

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Abstract

As the world increases its reliance on energy, the practice of adopting innovative, renewable energy sources has grown in significance. This study focuses on the effects of regulations and incentives on renewable energy financing in the U.S. The goal is to examine the connection between factors such as GDP and renewable energy financing. Using data from 2016 to 2019, a regression model is used to analyze how factors like GDP affect renewable energy consumption. Findings suggest that adopting certain renewable energy sources are more correlated with GDP, including solar, geothermal, biomass, and total renewable energy. In addition, economic factors were examined to determine which affected renewable energy consumption the most. The analysis suggested that the most effective energy source in the U.S. was solar, due to the high GDP in the U.S. as well as the rate of technological advancement in solar energy.

Introduction

The modeling of renewable energy finance is essential as the world begins to follow the guidelines of numerous climate agreements. The Paris Agreement focuses on reducing emissions in high-emission sectors by implementing zero-carbon solutions and considering the impact of policies on renewable energy construction [1].

Following the onset of the Russian invasion of Ukraine, global nations have been made aware of their energy supplies. Energy prices have surged at least 63% and up to 113% in some areas [2]. In addition, government spending worldwide has increased by $500 billion since the invasion [3]. The global energy economy's heavy reliance on Russian oil and gas has resulted in the consequence of this heavy reliance affecting certain regions significantly. A few years before the war started, two-thirds of European imports from Russia comprised energy-related products [4].

Even without the onset of the 'special military operation' over the past few years, renewable energy investment has also increased in many countries worldwide including China and India. In these two countries, the lack of a consistent energy supply in rural villages has become increasingly apparent. China still harbours 30 million people who do not have access to electricity [5]. In addition, India accounts for a third of the world's population who still do not have access to electricity [6]. Thus the need for energy becomes ever apparent, yet the method by which that electricity is generated has still leaned towards fossil fuels for centuries. Investment in fossil fuel energies remains as high as ever as over 1 trillion USD continues to go towards gas, coal, and oil. However, evidence points to the surge of renewable energy finance, in 2023, 1.7 trillion is set to be invested into clean technologies. Furthermore, for the first time, solar power is expected to exceed oil production [7]. This indicates the growing investment in renewable energy financing.

The importance of the way we finance clean technologies remains essential to effectively shifting the world away from fossil fuels. Specifically, financers tend to focus on obtaining finance instead of managing the financial assets effectively, this leads to skewed distribution of funds and leads to certain sectors of renewable energy research needing to be more balanced. (Mazzucato, Semieniuk, 2018, p.8) On the other hand, many factors come into consideration when building renewable energy infrastructure such as location, demand, capacity, and resource availability. Wind and Solar for instance require careful planning when erecting power plants. Wind in particular requires at least 9 mph for smaller winder turbines and 13 mph for utility-scale turbines, and not all locations are optimal [8].

Consequently, in the U.S. alone, five states comprised 57% of wind energy generation in 2022 [8]. In addition, Solar requires areas with high concentrations of solar radiation further highlighting the importance of location as California and Texas alone comprised 42% of utility-scale solar electricity [9]. Therefore, the financial planning of investment into renewable energies needs to be controlled and managed for further efficacy.

Our results find that GDP affects different types of renewable energy, however, the benefits of financing each renewable energy source differ, with some sources being better for public investors than others. In our data, we found that solar is currently the most prominent renewable energy source that is being developed and that it is a renewable energy source worth financing. This project will aim to explain why that is the case through regression analysis of energy consumption data from the IEA and research from outside sources.

Data

This research aims to find the most effective way to finance renewable energy. Using the data below, we analyze the relationships between different variables. In this project, data from 42 U.S. states is used and the data taken for the tables is from 2016-2019. The data is compiled from different sources and relisted as graphs and tables to help better understand the relationship between different variables. We were not able to acquire data for all U.S. states and variables; however, the data is still taken from a majority of U.S. states meaning that the results are still significant. The data is in a panel structure because we have time series and cross-sectional components. Some of the data samples are taken from the IEA, which lists detailed information on energy consumption and price. This data was directly implemented into our compiled data, which was then run through code and Excel to find the listed values in the tables below.

Results

We noticed many signs of collinearity throughout the results using the correlation matrix below. The closer to the red, which means 1, the more correlated they were. However, we excluded certain variables that displayed signs of multicollinearity to avoid biased estimates. We used a cutoff point of 0.8 to exclude certain variables such as energy consumption.

Table 1

Full data set on correlation between all variables used in the research paper.

Correlation Matrix of X Variables

	Real_GDP	Energy_Consumption	Number of Customers	Average Monthly Consumption	Average Price	Megawatt hour sales	Retail Energy Provider	Municipal	Other	Behind the Meter	Political Subdivision	Cooperative	Investor Owned	Federal	Retail Power Marketer	Bachelor's degree	Average Earnings
Real_GDP	1.00	0.83	0.78	0.00	0.11	0.78	0.42	0.09	0.09	0.37	0.05	0.11	0.38	0.10		0.18	0.21
Energy_Consumption	0.83	1.00	0.71	0.04	-0.11	0.89	0.78	0.16	0.05	0.09	-0.04	0.45	0.30	0.02		-0.02	-0.03
Number of Customers	0.78	0.71	1.00	-0.41	0.12	0.75	0.36	0.17	0.02	0.20	-0.00	0.18	0.34	0.11		0.08	0.08
Average Monthly Consumption	0.00	0.04	-0.41	1.00	-0.35	0.04	0.04	-0.11	0.08	-0.03	-0.01	0.04	-0.02	-0.01		-0.05	-0.06
Average Price	0.11	-0.11	0.12	-0.35	1.00	-0.17	-0.09	-0.17	0.03	0.53	-0.14	-0.46	0.10	0.02		0.37	0.48
Megawatt hour sales	0.78	0.89	0.75	0.04	-0.17	1.00	0.62	0.16	0.02	0.05	-0.05	0.43	0.29	0.06		-0.04	-0.10
Retail Energy Provider	0.42	0.78	0.36	0.04	-0.09	0.62	1.00	0.08	0.04	-0.00	-0.05	0.51	0.01	-0.03		-0.00	-0.06
Municipal	0.09	0.16	0.17	-0.11	-0.17	0.16	0.08	1.00	-0.24	-0.40	0.10	0.50	0.11	-0.11		0.04	-0.13
Other	0.09	0.05	0.02	0.08	0.03	0.02	0.04	-0.24	1.00	0.22	0.08	-0.04	-0.04	0.04		0.19	0.14
Behind the Meter	0.37	0.09	0.20	-0.03	0.53	0.05	-0.00	-0.40	0.22	1.00	-0.03	-0.51	0.16	0.30		0.39	0.53
Political Subdivision	0.05	-0.04	-0.00	-0.01	-0.14	-0.05	-0.05	0.10	0.08	-0.03	1.00	-0.15	-0.22	0.18		0.18	0.08
Cooperative	0.11	0.45	0.18	0.04	-0.46	0.43	0.51	0.50	-0.04	-0.51	-0.15	1.00	-0.02	-0.12		-0.20	-0.43
Investor Owned	0.38	0.30	0.34	-0.02	0.10	0.29	0.01	0.11	-0.04	0.16	-0.22	-0.02	1.00	0.09		-0.06	0.07
Federal	0.10	0.02	0.11	-0.01	0.02	0.06	-0.03	-0.11	0.04	0.30	0.18	-0.12	0.09	1.00		-0.03	-0.03
Retail Power Marketer																	
Bachelor's degree	0.18	-0.02	0.08	-0.05	0.37	-0.04	-0.00	0.04	0.19	0.39	0.18	-0.20	-0.06	-0.03		1.00	0.76
Average Earnings	0.21	-0.03	0.08	-0.06	0.48	-0.10	-0.06	-0.13	0.14	0.53	0.08	-0.43	0.07	-0.03		0.76	1.00

Table 2

Total Renewable Energy Consumption Compared with other Independent Variables and finding the variation the data can account for.

PanelOLS Estimation Summary

Dep. Variable:	Total Renewable	R-squared:	0.7851
Estimator:	PanelOLS	R-squared (Between):	-2.1278
No. Observations:	163	R-squared (Within):	0.7851
Date:	Sun, Nov 12 2023	R-squared (Overall):	-2.1103
Time:	16:29:19	Log-likelihood	-1767.0
Cov. Estimator:	Unadjusted		
		F-statistic:	27.923
Entities:	42	P-value	0.0000
Avg Obs:	3.8810	Distribution:	F(14,107)
Min Obs:	2.0000		
Max Obs:	4.0000	F-statistic (robust):	27.923
		P-value	0.0000
Time periods:	4	Distribution:	F(14,107)
Avg Obs:	40.750		
Min Obs:	38.000		
Max Obs:	42.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	-1.451e+05	9.669e+04	-1.5006	0.1364	-3.368e+05	4.659e+04
Real_GDP	0.3809	0.0828	4.6001	0.0000	0.2167	0.5450
Energy_Consumption	0.0970	0.0243	4.0016	0.0001	0.0490	0.1451
Number of Customers	-0.0089	0.0013	-6.9936	0.0000	-0.0114	-0.0063
Average Monthly Consumption	-0.1998	1.2064	-0.1656	0.8688	-2.5914	2.1918
Average Price	2695.8	1746.3	1.5438	0.1256	-765.93	6157.6
Megawatt hour sales	0.0051	0.0017	2.9750	0.0036	0.0017	0.0086
Municipal	475.48	115.60	4.1130	0.0001	246.31	704.65
Behind the Meter	4800.3	2512.9	1.9102	0.0588	-181.31	9781.8
Political Subdivision	-3.785e+04	4411.4	-8.5795	0.0000	-4.659e+04	-2.91e+04
Cooperative	-3090.6	2047.0	-1.5098	0.1341	-7148.6	967.47
Investor Owned	-5474.8	1.057e+04	-0.5178	0.6057	-2.644e+04	1.549e+04
Federal	1.781e+05	2.002e+04	8.8975	0.0000	1.384e+05	2.178e+05
Bachelor's degree	3841.2	5033.3	0.7631	0.4471	-6136.8	1.382e+04
Average Earnings	-2.8287	1.3749	-2.0574	0.0421	-5.5542	-0.1031

F-test for Poolability: 212.47
P-value: 0.0000
Distribution: F(41,107)

Included effects: Entity

Source: Data from *Electric Power Monthly - U.S. Energy Information Administration (EIA)*, EIA, 22 Nov. 2023, www.eia.gov/electricity/monthly/.

Note: Table 2 shows the fixed effects model results using total renewable energy consumption as the dependent variable. Time-fixed effects and state-fixed effects are used to account for time-invariant characteristics and deal with the limitations of omitted variable bias. The R squared is 0.7851, indicating that 78.51% of the variation in the dependent variable–total renewable energy consumption–is explained by our fixed effects model. Using the significance level of 5%, we can see that only the following variables are not significant: average monthly consumption, average price, behind the meter, cooperative, investor-owner, and bachelor's degree. This is a surprising result since I thought that education would affect the given dependent variable due to the increased knowledge that people would have on environmental topics. Yet this is not the case as shown with the P value. The coefficient with the Real GDP shows that an increase of one thousand dollars in Real GDP is partially correlated with an increase of 0.38 million BTU in total renewable energy consumption.

Table 3

Total Solar Energy Consumption Compared with other Independent Variables, and finding the variation the data can account for.

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                         PanelOLS Estimation Summary
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Dep. Variable:             Solar_MBtu   R-squared:                        0.8536
Estimator:                   PanelOLS   R-squared (Between):             -5.9986
No. Observations:                 163   R-squared (Within):               0.8536
Date:                Sun, Nov 12 2023   R-squared (Overall):             -5.7610
Time:                        16:34:12   Log-likelihood                   -1565.7
Cov. Estimator:            Unadjusted
                                        F-statistic:                      44.577
Entities:                          42   P-value                           0.0000
Avg Obs:                       3.8810   Distribution:                   F(14,107)
Min Obs:                       2.0000
Max Obs:                       4.0000   F-statistic (robust):             44.577
                                        P-value                           0.0000
Time periods:                       4   Distribution:                   F(14,107)
Avg Obs:                       40.750
Min Obs:                       38.000
Max Obs:                       42.000

                                     Parameter Estimates
================================================================================================
                           Parameter  Std. Err.     T-stat    P-value    Lower CI    Upper CI
------------------------------------------------------------------------------------------------
const                      -1.171e+05  2.812e+04    -4.1633     0.0001  -1.728e+05  -6.133e+04
Real_GDP                       0.4244     0.0241     17.625     0.0000      0.3767      0.4722
Energy_Consumption            -0.0258     0.0071    -3.6570     0.0004     -0.0398     -0.0118
Number of Customers           -0.0009     0.0004    -2.5764     0.0113     -0.0017     -0.0002
Average Monthly Consumption    0.2265     0.3509     0.6457     0.5199     -0.4690      0.9221
Average Price                  703.46     507.88     1.3851     0.1689     -303.35      1710.3
Megawatt hour sales            0.0011     0.0005     2.1593     0.0331   8.895e-05      0.0021
Municipal                     -24.945     33.622    -0.7419     0.4598     -91.597      41.707
Behind the Meter               463.04     730.85     0.6336     0.5277     -985.78      1911.9
Political Subdivision         -2441.1     1283.0    -1.9027     0.0598     -4984.5      102.24
Cooperative                   -454.64     595.36    -0.7637     0.4468     -1634.9      725.58
Investor Owned                 342.20     3075.1     0.1113     0.9116     -5753.9      6438.3
Federal                      1.05e+04     5822.8     1.8027     0.0743     -1046.4   2.204e+04
Bachelor's degree              366.00     1463.9     0.2500     0.8030     -2536.0      3268.0
Average Earnings              -0.5317     0.3999    -1.3297     0.1864     -1.3244      0.2610
================================================================================================

F-test for Poolability: 124.44
P-value: 0.0000
Distribution: F(41,107)

Included effects: Entity
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Source: Data from *Electric Power Monthly - U.S. Energy Information Administration (EIA)*, EIA, 22 Nov. 2023, www.eia.gov/electricity/monthly/.

Note: Table 3 shows the fixed effects model results using total solar energy consumption as the dependent variable. The data uses time- and state-fixed effects to reduce omitted variable bias and account for variables that change due to time factors. The R squared is 0.8536, indicating that 85.36% of the variation in the dependent variable can be explained through the model. Keeping in mind the significance level of 5%, we can see that the variables average monthly consumption, behind the meter, investor-owned, average price, municipal, political subdivision, cooperative, federal, average earnings, and bachelor's degree are **not** significant. This is surprising because I thought that education would affect renewable energy consumption as a more educated populace would be able to identify the effects of climate change and attempt to reduce their carbon footprint. The coefficient with the Real GDP, shows that an increase of one thousand dollars in Real GDP leads to an increase of 0.42 million BTU in solar energy consumption.

Table 4

Total Solar Energy Consumption Compared with other Independent Variables and finding the variation the data can account for.

PanelOLS Estimation Summary

Dep. Variable:	Wind_MBtu	R-squared:	0.7816
Estimator:	PanelOLS	R-squared (Between):	-2.5768
No. Observations:	163	R-squared (Within):	0.7816
Date:	Sun, Nov 12 2023	R-squared (Overall):	-2.5205
Time:	16:34:44	Log-likelihood	-1668.7
Cov. Estimator:	Unadjusted		
		F-statistic:	27.349
Entities:	42	P-value	0.0000
Avg Obs:	3.8810	Distribution:	F(14,107)
Min Obs:	2.0000		
Max Obs:	4.0000	F-statistic (robust):	27.349
		P-value	0.0000
Time periods:	4	Distribution:	F(14,107)
Avg Obs:	40.750		
Min Obs:	38.000		
Max Obs:	42.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	-1.445e+05	5.291e+04	-2.7317	0.0074	-2.494e+05	-3.964e+04
Real_GDP	-0.0782	0.0453	-1.7261	0.0872	-0.1680	0.0116
Energy_Consumption	0.1625	0.0133	12.250	0.0000	0.1362	0.1888
Number of Customers	-0.0010	0.0007	-1.4809	0.1416	-0.0024	0.0003
Average Monthly Consumption	-0.3177	0.6601	-0.4813	0.6313	-1.6263	0.9909
Average Price	-828.47	955.52	-0.8670	0.3879	-2722.7	1065.7
Megawatt hour sales	-0.0025	0.0009	-2.6463	0.0094	-0.0044	-0.0006
Municipal	365.07	63.256	5.7712	0.0000	239.67	490.47
Behind the Meter	2989.7	1375.0	2.1743	0.0319	263.90	5715.5
Political Subdivision	-2282.6	2413.8	-0.9456	0.3465	-7067.6	2502.5
Cooperative	-1310.7	1120.1	-1.1702	0.2445	-3531.2	909.72
Investor Owned	1235.6	5785.5	0.2136	0.8313	-1.023e+04	1.27e+04
Federal	9225.4	1.095e+04	0.8421	0.4016	-1.249e+04	3.094e+04
Bachelor's degree	-3208.3	2754.1	-1.1649	0.2466	-8668.0	2251.4
Average Earnings	0.5368	0.7523	0.7136	0.4770	-0.9545	2.0282

F-test for Poolability: 166.44
P-value: 0.0000
Distribution: F(41,107)

Included effects: Entity

Source: Data from *Electric Power Monthly - U.S. Energy Information Administration (EIA)*, EIA, 22 Nov. 2023, www.eia.gov/electricity/monthly/.

Note: With total wind energy consumption as the dependent variable, the findings of the fixed effects model are displayed in Table 4. Temporal- and state-fixed effects are used in the data to account for variables that vary as a result of temporal factors and minimize the bias caused by omitted variables. With an R squared of 0.7816, the model can account for 78.16% of the variation observed in the dependent variable. The average monthly consumption, investor-owned, number of customers, average price, political subdivision, cooperative, Real GDP, federal, bachelor's degree, and average earnings variables are **not** significant, according to the 5% significance level. This is unexpected since, as Table 1 explains, we expected education to have an impact on the dependent variable; however, this is not the case because the effect is not statistically significant. Federal is also not significant, which is also surprising considering the government often invests in wind energy.

Table 5

Total Hydropower Energy Consumption Compared with other Independent Variables and finding the variation the data can account for.

PanelOLS Estimation Summary

Dep. Variable:	Hydropower_MBtu	R-squared:	0.5822
Estimator:	PanelOLS	R-squared (Between):	-3.9599
No. Observations:	163	R-squared (Within):	0.5822
Date:	Sun, Nov 12 2023	R-squared (Overall):	-3.9118
Time:	16:35:13	Log-likelihood	-1732.5
Cov. Estimator:	Unadjusted		
		F-statistic:	10.649
Entities:	42	P-value	0.0000
Avg Obs:	3.8810	Distribution:	F(14,107)
Min Obs:	2.0000		
Max Obs:	4.0000	F-statistic (robust):	10.649
		P-value	0.0000
Time periods:	4	Distribution:	F(14,107)
Avg Obs:	40.750		
Min Obs:	38.000		
Max Obs:	42.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	-2.252e+04	7.823e+04	-0.2878	0.7740	-1.776e+05	1.326e+05
Real_GDP	-0.0293	0.0670	-0.4380	0.6623	-0.1621	0.1035
Energy_Consumption	-0.0414	0.0196	-2.1114	0.0371	-0.0803	-0.0025
Number of Customers	-0.0066	0.0010	-6.4256	0.0000	-0.0086	-0.0046
Average Monthly Consumption	0.1766	0.9761	0.1809	0.8568	-1.7584	2.1115
Average Price	2965.5	1412.8	2.0990	0.0382	164.73	5766.2
Megawatt hour sales	0.0067	0.0014	4.7896	0.0000	0.0039	0.0095
Municipal	123.73	93.531	1.3229	0.1887	-61.684	309.14
Behind the Meter	2501.7	2033.1	1.2305	0.2212	-1528.7	6532.0
Political Subdivision	-3.202e+04	3569.0	-8.9714	0.0000	-3.909e+04	-2.494e+04
Cooperative	-881.01	1656.2	-0.5320	0.5959	-4164.2	2402.2
Investor Owned	-7627.8	8554.4	-0.8917	0.3746	-2.459e+04	9330.4
Federal	1.39e+05	1.62e+04	8.5834	0.0000	1.069e+05	1.711e+05
Bachelor's degree	7978.1	4072.2	1.9591	0.0527	-94.631	1.605e+04
Average Earnings	-2.6620	1.1123	-2.3931	0.0184	-4.8671	-0.4569

F-test for Poolability: 194.63
P-value: 0.0000
Distribution: F(41,107)

Included effects: Entity

Source: Data from *Electric Power Monthly - U.S. Energy Information Administration (EIA)*, EIA, 22 Nov. 2023, www.eia.gov/electricity/monthly/.

Note: With total hydroenergy consumption as the dependent variable, the fixed effects model's findings are shown in Table 5. Temporal- and state-fixed effects are added to the data to reduce the bias arising from omitted variables and account for variables that fluctuate owing to temporal conditions. With an R squared of 0.5822, the model accounts for 58.22% of the variance observed in the dependent variable. At the 5% significance level, the energy consumption, the number of customers, megawatt-hour sales, average price, political subdivision, federal, and average earnings variables are all significant. This is expected, as the government is the main financier of hydropower due to the scale of the construction projects for hydro dams. Real GDP is not a significant factor, which is important to consider.

Table 6

Total Geothermal Energy Consumption Compared with other Independent Variables and finding the variation the data can account for.

PanelOLS Estimation Summary

Dep. Variable:	Geothermal_MBtu	R-squared:	0.6155
Estimator:	PanelOLS	R-squared (Between):	-0.3197
No. Observations:	163	R-squared (Within):	0.6155
Date:	Sun, Nov 12 2023	R-squared (Overall):	-0.3187
Time:	16:35:38	Log-likelihood	-1222.0
Cov. Estimator:	Unadjusted		
		F-statistic:	12.233
Entities:	42	P-value	0.0000
Avg Obs:	3.8810	Distribution:	F(14,107)
Min Obs:	2.0000		
Max Obs:	4.0000	F-statistic (robust):	12.233
		P-value	0.0000
Time periods:	4	Distribution:	F(14,107)
Avg Obs:	40.750		
Min Obs:	38.000		
Max Obs:	42.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	4142.9	3413.3	1.2137	0.2275	-2623.7	1.091e+04
Real_GDP	-0.0101	0.0029	-3.4674	0.0008	-0.0159	-0.0043
Energy_Consumption	0.0008	0.0009	0.9040	0.3680	-0.0009	0.0025
Number of Customers	-5.451e-05	4.469e-05	-1.2197	0.2252	-0.0001	3.408e-05
Average Monthly Consumption	-0.0259	0.0426	-0.6084	0.5442	-0.1103	0.0585
Average Price	-59.629	61.644	-0.9673	0.3356	-181.83	62.573
Megawatt hour sales	7.149e-05	6.103e-05	1.1713	0.2441	-4.95e-05	0.0002
Municipal	2.2633	4.0809	0.5546	0.5803	-5.8266	10.353
Behind the Meter	-47.927	88.707	-0.5403	0.5901	-223.78	127.92
Political Subdivision	970.97	155.72	6.2352	0.0000	662.26	1279.7
Cooperative	46.908	72.261	0.6491	0.5176	-96.342	190.16
Investor Owned	33.541	373.24	0.0899	0.9286	-706.37	773.45
Federal	-6247.7	706.74	-8.8402	0.0000	-7648.8	-4846.7
Bachelor's degree	-80.509	177.68	-0.4531	0.6514	-432.74	271.72
Average Earnings	0.0221	0.0485	0.4549	0.6501	-0.0741	0.1183

F-test for Poolability: 1078.0
P-value: 0.0000
Distribution: F(41,107)

Included effects: Entity

Source: Data from *Electric Power Monthly - U.S. Energy Information Administration (EIA)*, EIA, 22 Nov. 2023, www.eia.gov/electricity/monthly/.

Note: Table 6 displays the results of the fixed effects model using total geothermal consumption as the dependent variable. To account for variables that change due to temporal circumstances and to lessen the bias resulting from omitted variables, temporal- and state-fixed effects are added to the data. The model explains 61.55% of the variation seen in the dependent variable, with an R squared of 0.6155. The only significant variables are Real GDP, political subdivision, and federal. This is expected, as geothermal is less commonly invested in and financed by the public sector; wind and solar are often more popular choices. The correlation between geothermal energy consumption and Real GDP indicates that an increase in Real GDP of $1,000 is associated with a corresponding decrease in geothermal energy consumption of 0.0101 million BTU.

Table 7

Total Biomass Energy Consumption Compared with other Independent Variables and finding the variation the data can account for.

PanelOLS Estimation Summary

Dep. Variable:	Biomass_MBtu	R-squared:	0.3989
Estimator:	PanelOLS	R-squared (Between):	0.2880
No. Observations:	163	R-squared (Within):	0.3989
Date:	Sun, Nov 12 2023	R-squared (Overall):	0.2926
Time:	16:35:42	Log-likelihood	-1570.4
Cov. Estimator:	Unadjusted		
		F-statistic:	5.0712
Entities:	42	P-value	0.0000
Avg Obs:	3.8810	Distribution:	F(14,107)
Min Obs:	2.0000		
Max Obs:	4.0000	F-statistic (robust):	5.0712
		P-value	0.0000
Time periods:	4	Distribution:	F(14,107)
Avg Obs:	40.750		
Min Obs:	38.000		
Max Obs:	42.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
const	1.349e+05	2.895e+04	4.6597	0.0000	7.75e+04	1.923e+05
Real_GDP	0.0741	0.0248	2.9903	0.0035	0.0250	0.1233
Energy_Consumption	0.0009	0.0073	0.1292	0.8975	-0.0135	0.0153
Number of Customers	-0.0002	0.0004	-0.6421	0.5222	-0.0010	0.0005
Average Monthly Consumption	-0.2593	0.3612	-0.7180	0.4743	-0.9753	0.4566
Average Price	-85.000	522.78	-0.1626	0.8711	-1121.3	951.35
Megawatt hour sales	-0.0002	0.0005	-0.4055	0.6859	-0.0012	0.0008
Municipal	9.3626	34.609	0.2705	0.7873	-59.245	77.970
Behind the Meter	-1106.2	752.29	-1.4705	0.1444	-2597.6	385.09
Political Subdivision	-2075.5	1320.6	-1.5716	0.1190	-4693.4	542.52
Cooperative	-491.07	612.82	-0.8013	0.4247	-1705.9	723.77
Investor Owned	541.61	3165.3	0.1711	0.8645	-5733.3	6816.5
Federal	2.563e+04	5993.6	4.2760	0.0000	1.375e+04	3.751e+04
Bachelor's degree	-1214.1	1506.8	-0.8057	0.4222	-4201.2	1773.0
Average Earnings	-0.1939	0.4116	-0.4711	0.6385	-1.0099	0.6220

F-test for Poolability: 354.42
P-value: 0.0000
Distribution: F(41,107)

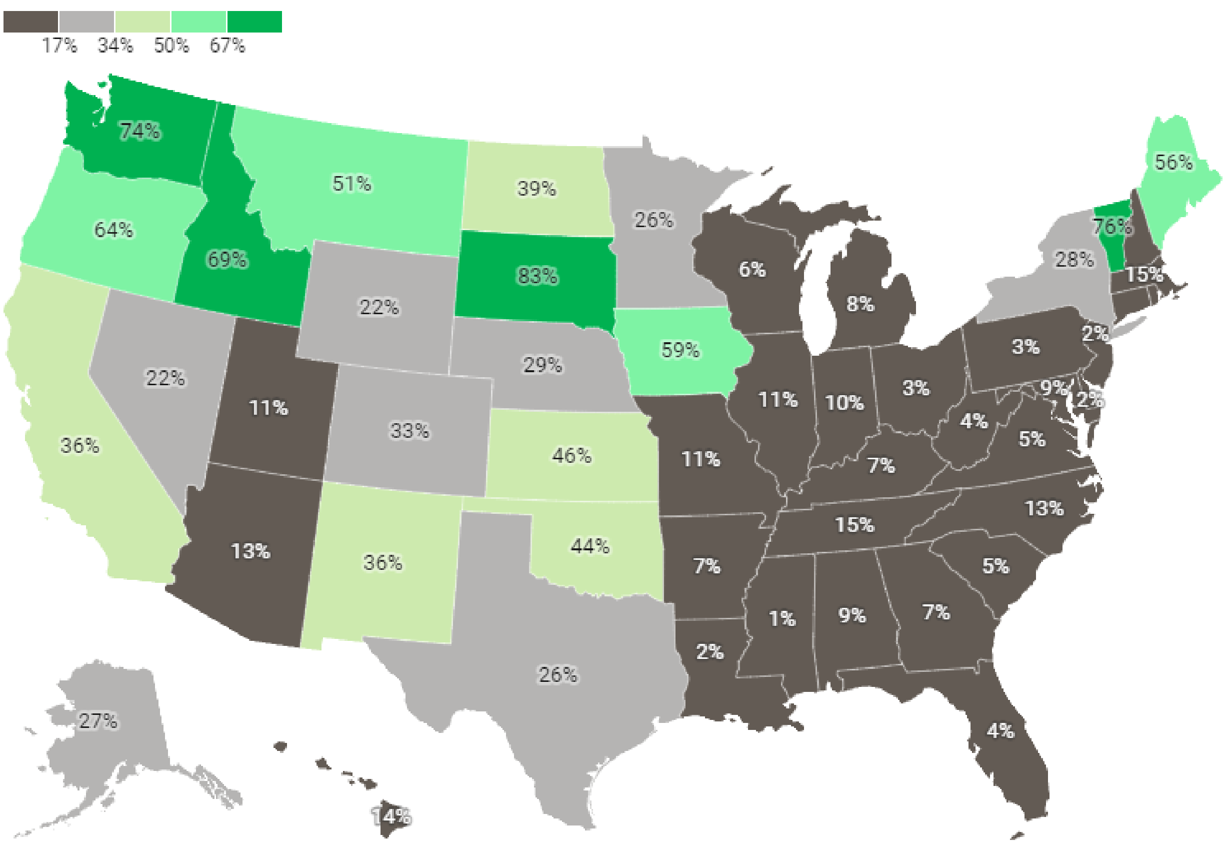
Included effects: Entity

Source: Data from *Electric Power Monthly - U.S. Energy Information Administration (EIA)*, EIA, 22 Nov. 2023, www.eia.gov/electricity/monthly/.

Note: With total biomass use as the dependent variable, the fixed effects model's findings are shown in Table 7. State- and temporal-fixed effects are added to the data to reduce the bias caused by missing variables and account for factors that vary with temporal conditions. With an R squared of 0.3989, the model accounts for 39.89% of the variance observed in the dependent variable. Only two variables—Real GDP and Federal—are statistically significant at the 5% significance level. These results are somewhat expected, as the government mainly funds biomass operations and biomass investment opportunities are not as easily accessible to public investors. Thus, it is not as easily financeable as other renewable energy sources like solar and wind. In addition, biomass energy consumption increases by 0.0741 million BTU for every

$1,000 rise in Real GDP, according to the link between biomass energy consumption and Real GDP.

Fig. 1. A map showing the percentage of total renewable energy production in each state from Kirk, Karin. “Which State Is Winning at Renewable Energy Production? " Yale Climate Connections.” Yale Climate Connections, 1 May 2023, yaleclimateconnections.org/2023/02/us-state-with-most-renewable-energy-production/.



Note: This map shows the raw percentage of energy demand fulfilled by renewable energy in each U.S. state with the range being between 1% and 83%. In this case, brighter colors mean more renewable energy production and darker colors mean less renewable energy production. As shown in the map, Eastern states have a significantly lower level of renewable energy in their energy portfolios when compared with Western states like California, Oregon, and Washington.

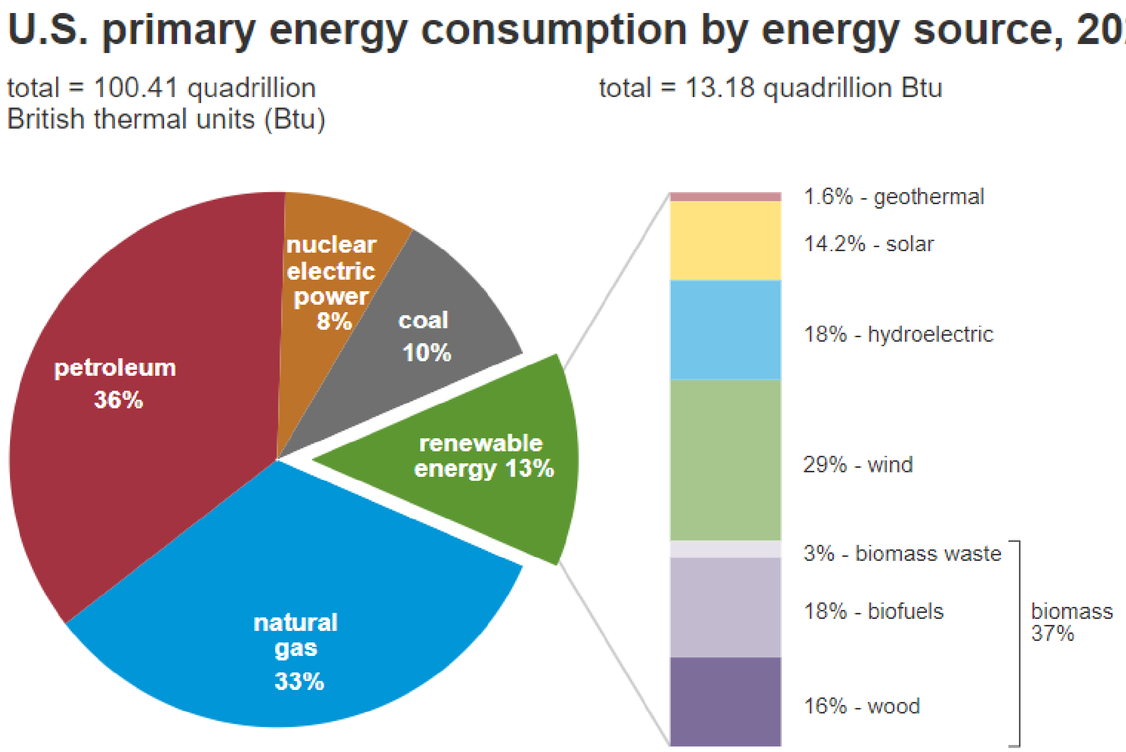


Fig. 2. The energy consumption portfolio of the U.S. in 2022 from "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." *U.S. Energy Facts Explained - Consumption and Production - U.S. Energy Information Administration (EIA)*, EIA, Apr. 2023, www.eia.gov/energyexplained/us-energy-facts/.

Note: The table shows that there is a heavy reliance on biomass currently which makes up most of the renewable energy. However, solar, hydro, and wind are all getting close to the amount of biomass energy consumed, meaning that biomass is slowly losing relevance. In addition, U.S. energy needs are mostly covered by petroleum and natural gas meaning that a shift away from these fuel sources will take a long period.

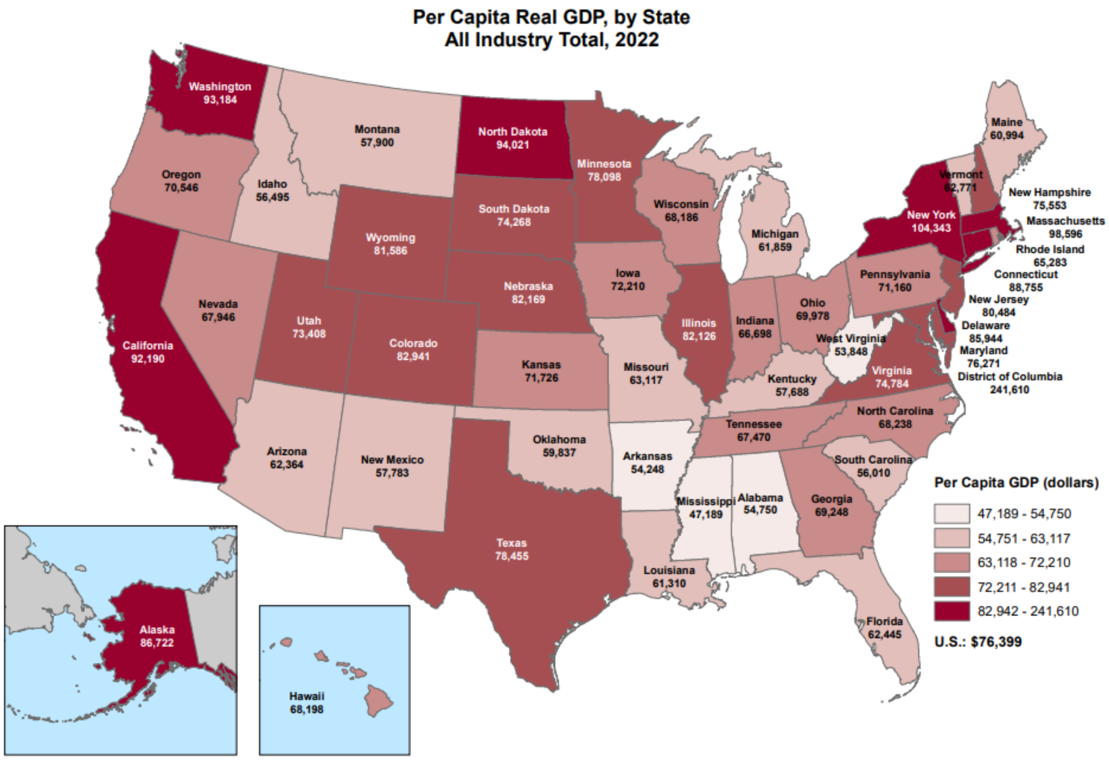


Fig. 3. A map of the U.S. displaying the per capita Real GDP by state from *Per Capita Real GDP, by State All Industry Total, 2022*, The University of Kansas, 2022, ipsr.ku.edu/ksdata/ksah/business/percapGDP.pdf.

Note: The map shows that Western states tend to have higher per capita real GDP compared to the Eastern States, except states like New York, and Massachusetts. In general, the North also tends to have a higher per capita GDP, as shown by the lighter colors at the bottom of the map compared to the top.

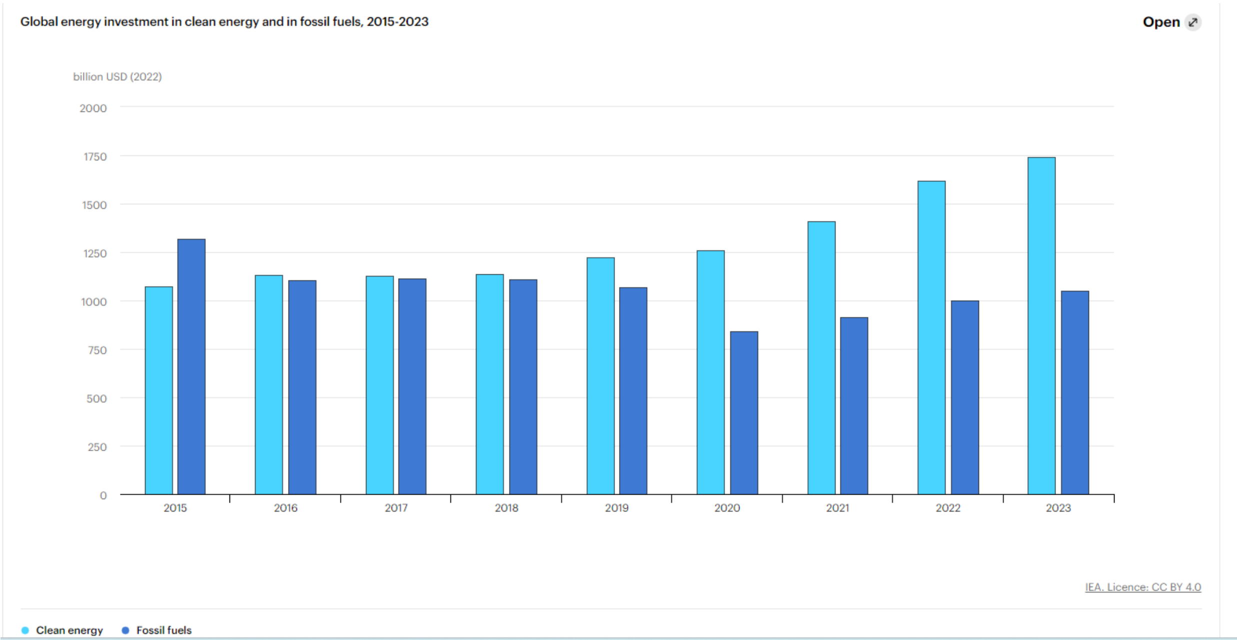


Fig. 4. Global investment into clean energy compared with fossil fuel investment over 8 years, with light blue being clean energy, and dark blue being fossil fuel energy from "Overview and Key Findings – World Energy Investment 2023 – Analysis." *IEA*, IEA, 2023, www.iea.org/reports/world-energy-investment-2023/overview-and-key-findings.

Note: This table shows the growing trend of renewable energy investment around the globe, which also applies to the U.S. It also helps explain the development of cheaper solar, wind and other renewables. It also signals the growing obscurity of fossil fuels.

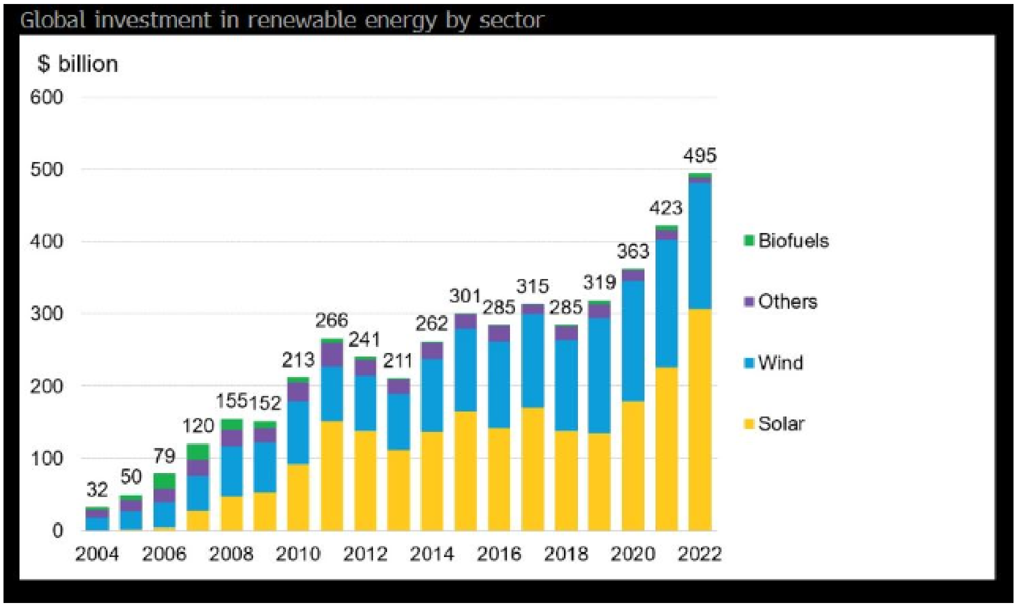


Fig. 5. Global investment into renewable energy by sector in billions of USD from "A Record $495 Billion Invested in Renewable Energy in 2022." *BloombergNEF*, Bloomberg, 2 Feb. 2023, about.bnef.com/blog/a-record-495-billion-invested-in-renewable-energy-in-2022/.

Note: In most of the table, wind energy has seen heavy investments while solar investments have increased over time, passing wind in total investments in 2016-2022. By contrast, other renewable energy sources like biofuels have not been as heavily invested in. This is significant as it shows that wind and solar are the most popular choices in terms of financing for many countries around the world.

Financing Solar

Throughout the U.S., there is existing renewable energy infrastructure in many places; however, the existing infrastructure cannot support full electrification. This also indicates that it does not provide enough power to support a switch to a fully renewable portfolio. In some states, less than 10% of their required energy is renewable (see Fig. 1). Other states with more existing renewable energy production can reach a 100% renewable portfolio more quickly, as shown by the Western states where renewable energy makes up near 50% of their energy portfolio (see Fig. 1).

When taking this into account, it is important to note that some states are more well-suited to adopt renewable energy. For example, there is a strong positive correlation between total renewable infrastructure and GDP, meaning that states with a stronger GDP have a stronger financial base to invest in and better finance renewable energy (see Table. 1). Solar prices have also dropped significantly since the start of the 21st century: the average solar system cost $10 per watt in the early 2000s, and has since decreased to $0.1 per kWh [10]. This trend is likely to continue as solar technology improves.

Though solar has a significant influence on renewable energy now, other existing renewable energy sources are also making a difference in the shift toward more renewable energy sourcing. The majority of U.S. renewable energy comes from biomass, hydro, wind, and solar (see Fig. 2). Despite better solar technology, wind, biomass, and hydro still make up more renewable energy production than solar (see Fig. 2). However, solar has only recently become more efficient as mass production of solar panels has become more effective and existing technology has been improved. In the U.S., 46% of all new generating capacity in 2021 came from solar [11]. Solar is being developed at a rapid rate and investors have been quick to notice the changes that new solar technology has brought.

According to Table 1, 85.36% of the variation in the variable, Solar energy consumption, can be explained through the fixed effects model. This means that the Real GDP is heavily correlated with more solar energy consumption, meaning that the stronger a state's economy is, the more consumption of solar energy there will be. Thus, there will be a larger market for financers of this area. This is also supported by the data shown in Figures 1 and 3, as the states with a higher GDP tend to invest more in renewables which end up making up more of their energy portfolio. This isn't without its exceptions, however, as North Dakota and New York have a high GDP yet a lower amount of their energy portfolio is made up of renewables (see Figs. 1 and 3).

Another factor that warrants consideration is that a highly educated populace does not have a significant effect on the amount of solar energy consumption in a given state (see Table 2). This doesn't fully discount education's impact on solar energy consumption; however, educated individuals tend to perceive climate change and other social and environmental issues as more significant [12]. This means that education may have an impact, but further research is needed to determine whether there is a true correlation between the two variables.

Solar also has many other factors that need to be considered while investing in solar, as temperature, sunlight, and weather can affect energy production from a solar panel [13]. From outside data and this research, it is concludable that financing solar is more effective in higher GDP states with good weather conditions, and is a technology that is still developing to be more cost-effective.

Financing Wind

Wind infrastructure is lacking when it comes to meeting all energy demands. However, it still makes up 29% of U.S. renewable energy production (see Fig. 2). The U.S. government has also invested $12 billion in capital investment in wind [14], making it the second most invested renewable energy by the government, with federal solar investment ranking first. With wind being one of the top substitutes for solar, it is one of the most important renewable energy sources to consider when financing.

Wind is currently one of the most cost-effective renewable energy sources with advances in scientific technology [14]. It is also able to be utilized in urban settings by building wind farms on the periphery of a city or by integrating a wind energy design into a building [15]. This is similar to solar and makes it optimal for investment because it is usable in residential and urban settings.

Due to these factors, wind still carries a majority of the load in the renewable energy portfolio with 29% of energy consumption coming from wind energy (see Fig. 2). Global energy investment into wind has also skyrocketed in recent years because of new developing technology (see fig. 5). This includes the U.S. as they have invested the second most amount, falling behind China in investment [16].

When financing wind, the previous factors are important, but one important factor analyzed in this research was Real GDP and its correlation with wind energy consumption. The data showed, however, that Real GDP is not a significant variable, according to the 5% significance factor, when tied to wind energy consumption (see Table. 3). This is quite unexpected because, with a stronger economy, it would seem that there would be heavier consumption of wind energy due to heavier investment into wind energy. Yet, this is not the case according to the data shown. This could be explained by how the model accounts for 78.16% of the variation observed in the dependent variable; however, a stronger explanation would be that more investment is put into solar, thus meaning that solar is the renewable energy most affected by Real GDP (see fig. 2).

Fossil fuels also continue to make up a majority of the energy portfolio in the U.S. meaning that investment is also often put into other energy production sources. An estimated $20 billion of taxpayer money continues to go into the fossil fuel industry [17]. This means that, although wind energy is one of the more heavily invested in renewable energies, due to other sources of existing energy, other renewable energy sources, and new emerging technologies in other sectors, an increase in GDP is not significant to the increase in consumption of wind energy in the U.S.

Financing Hydropower

Hydropower has long been used by nations and is still currently one of the main renewable energy sources for the U.S. It makes up 18% of all renewable energy consumption, which is less than wind, but still significant (see Fig. 2). Even today, the Biden administration has continued to finance hydropower projects, with $13 million financed towards development of hydropower [18].

Hydro is often a more consistent energy source than others because it relies on running water [19]. It is also longer lasting than other renewables because of the integrity of dams and it is also much more concentrated, making it easier to distribute [20]. Yet, large-scale projects are often mainly funded by the government, for instance, the total construction cost for hydro was around $2.5 billion in 2016 [21]. This means that the amount of finance required to construct hydro is out of reach for many public investors due to the lack of financial assets required.

Our model accounts for 58.22% of the variation observed in the dependent variable, which in this case is hydroenergy consumption (see Table. 4). It is also significant that Real GDP is not a significant factor when it comes to hydroenergy consumption (see Table. 4). Instead, federal, and political subdivision come out to be significant, which is important because it shows how government finance in the U.S. is the main driving factor behind the industry. It is important to note that small-scale hydro can also be invested in by public investors, but the main production of hydro energy comes from larger-scale projects. This is represented in the data by the significance of the variables of federal and political subdivision on the dependent variable.

While hydro continues to be a part of the transition to a fully renewable energy portfolio, the fact remains that it is also restricted by location and size. Hydropower needs a consistent water supply and a large amount of land [22]. The investment into hydro is also often long-term, meaning that public investors have less reason to finance these projects due to the high risk for returns that may take many years to activate. Thus, hydro may be an important renewable energy source, but from a financial perspective, it is not one of the most effective renewable energies to finance.

Financing Biomass and Geothermal

Biomass and Geothermal are often less financed by investors as they are often only used in niche situations. Geothermal is heavily constricted by location and it is quite expensive to invest in [23]. On the other hand, biomass is also quite inefficient and can cause emissions if fuel is not burned effectively [24]. Yet, despite these inefficiencies, they still need to be considered as they are still actively invested in and still make up a portion of the renewable energy portfolio in the U.S.

In the U.S. geothermal, has up to $165 million in federal investments [25]. The U.S. is also the leading global producer of geothermal energy [26] and has invested $1.029 billion in biomass [27]. This shows that, although these energies are somewhat inefficient, they are still invested in.

With financing biomass, our model can account for 39.89% of the variation observed in the dependent variable. There are only two significant variables in the model, Real GDP and Federal (see table. 6). This means that, currently, biomass is most influenced by the government and is not as heavily financed by public investors. Biomass energy consumption also increases by 0.0741 million BTU for every $1,000 rise in Real GDP, according to the link between biomass energy consumption and Real GDP (see table 6). However, the model only accounts for around 40% of the variation in the dependent variable, which in this case is biomass energy consumption meaning that the dependent variable is less correlated with the independent variables.

Biomass as energy overall has been in use for many years and still makes up 37% of renewable energy (see fig. 2). Yet, it is not entirely clean and is not financed through public means. It is often financed by government streams according to our data, as there are only two significant independent variables. However, biomass is also cheap and easy to use, and it has been used in the past as the main source of energy [28]. Biomass cannot be discounted as an important renewable energy to shift into, however, looking at it from a financial perspective, it is not the most efficient renewable energy source to invest in, in the modern world.

Financing geothermal energy is an entirely different matter. Our model explains 61.55% of the variation seen in the dependent variable, and there are only three significant variables within our data:
Real GDP, political subdivision, and federal. This shows that a rise of $1,000 in Real GDP is associated with a corresponding decrease in geothermal energy consumption of -0.0101 million BTU (see Table. 5). It also means that the government is more involved in the financing of geothermal energy as well as indicated by the significance of the variables federal, and political

subdivision (see table. 5). The fact that the more GDP increases, the less geothermal energy is consumed implies that financing geothermal in the U.S. is not extremely cost-effective.

This can be explained by the geographical limitations of geothermal as well as the limiting factor of construction. Geothermal is heavily limited by location as it relies on places with volcanoes, hot springs, and geysers [29]. This means that this technology cannot be readily integrated into urban settings and is not as easily accessible to public financing. Despite the difficulty of financing geothermal, the government still invests money into the technology, albeit significantly less than solar and wind. It also still makes up 1.6% of renewable energy consumption in the U.S. Overall, geothermal has also been used around the world for 80 years and will still be part of the process of transitioning to all renewable energies [30].

Conclusion

After doing research and data gathering, we have drawn multiple conclusions from the research. One main finding would be that extensive education does not affect energy consumption, meaning that a populace with a bachelor's degree does not necessarily account for more renewable energy investment. Another major finding would be that wind and solar are the top contenders for public finance as they are the most easily accessible technologies. In addition, they are also able to be used in urban environments, making them more accessible to the general public. Furthermore, solar energy consumption is heavily correlated with Real GDP meaning that richer states often have more solar energy consumption, meaning that there should be more emphasis put on financing solar energy. Wind energy does not do the same, yet it is still the second most invested in renewable energy today in the modern world. Other renewable energies such as hydro, biomass, and geothermal on the other hand are more influenced by federal financing and are not as easily publicly financible. Although the U.S. government continues to invest in these technologies, it is still significantly less financed than other renewable energies such as wind and solar. With solar and wind technology developing at such a rapid rate, prices for wind and solar will inevitably decrease with time. Overall, the research done has brought forth some surprising and some expected outcomes, and it has shown that financing solar and wind is the most effective way to transition into renewable energies in the future in the U.S., and many countries around the world have already started in this shift.

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