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Carbon, Growth and Politics: U.S. States in the Early 21st Century*

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Abstract: The transition to lower-carbon energy sources has been described as the biggest social-technical challenge ever to face humans. This transition involves a roll-out of new technologies following decisions motivated by economic factors as well as political preferences. In this address I describe how this process has unfolded since 2000 using state-level energy data, while also examining the relationships among adoption, economic growth and political voting preferences. One key finding is the growing correlation since 1992 between the vote share of the Republican presidential candidate and CO_2 emissions per capita, despite the growing adoption of green energy even in so-called red states. The paper concludes with a few recommendations for research, including the need to better understand growing community resistance to renewable energy sources and their community wide impacts.

Keywords: CO_2 emissions, energy transition, GDP growth, voting

JEL Codes: D72, Q40, Q54, R11

1. INTRODUCTION

Two remarkable energy-related developments of the early 21st Century are the growing U.S. energy independence coupled with the declining energy intensity of the economy. Here I review how this story has played out across the States as reflected in energy use, carbon emissions, economic growth, and evolving energy politics evident from voters' political choices. State patterns of energy production and carbon emissions are reviewed in Section 2, while Section 3 explores the relationship among per capita income growth and energy development and carbon emissions as well as basic well-being more generally. It also includes simple income growth convergence regressions. Section 4 considers the relationships between changing political preferences and the use of renewable energy, as well as carbon emissions, and the rising pushback against renewables. The last section briefly outlines challenges ahead along

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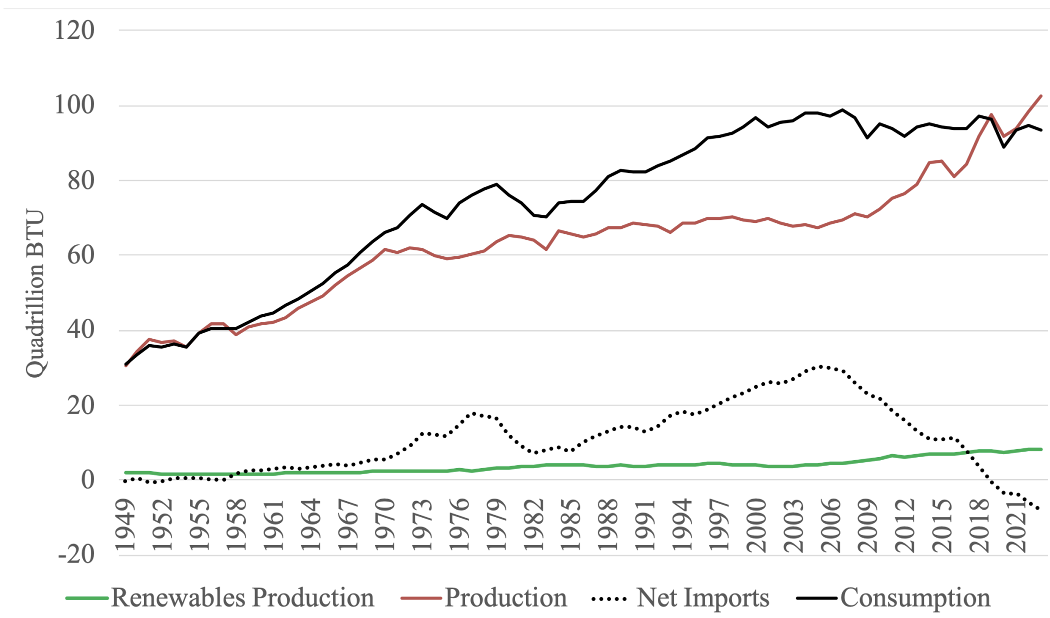
with a few research questions for regional scientists. The paper is largely descriptive and exploratory, rather than seeking to establish causal relationships, which are to some extent addressed in Zheng et al. (2024).

2. ENERGY AND CARBON TRENDS

2.1. National Trends

Three significant trends stand out in the recent history of the U.S. energy sector (Figure 1). First, U.S. total primary energy consumption is lower in 2023 that at the turn of the Century, reflecting the declining energy intensity of the economy, measured in British Thermal Units (Btu) per constant $GDP, or greater efficiency in using energy to produce output. This follows a more than tripling of U.S. primary energy consumption from 1950 to 2007, when it reached 99.0 quadrillion (qn) Btu. In comparison, real U.S. GDP expanded more than 7-fold during this period.[1] The effects of the OPEC price war in the early 1970s and late 1980's, and the 2007/08 recessions, as well as the Covid-19 pandemic are also visible in the energy consumption line.

Figure 1: U.S. Primary Energy Overview, 1949-2023



Source: Author, using U.S. EIA data from the *October 2024 Monthly Energy Review* Note: Data refer to total primary energy in quadrillion Btus, except for renewables production. https://www.eia.gov/totalenergy/data/monthly/index.php#summary

After doubling between 1950 and 1971, U.S. primary energy production expanded more gradually in the following three decades, by about 20 qn. Btu to the year 2000. Since 2007, primary energy production has risen once again, by 30 qn Btu, with the advent of hydraulic fracking and the introduction of energy generation from renewable energy sources, including

[1]See: https://fred.stlouisfed.org/series/GDPC1

nuclear (U.S. Energy Information Administration, 2024a)[2]. Equally remarkable, renewable sources of energy have consistently comprised around 8% to 9% of total production since 2010.

The two key trends – rapid increases in domestic energy production on the one hand, and energy consumption stabilizing or even declining, on the other, produced a watershed moment in 2019 when the U.S. became a net energy exporter for the first time since the late 1950s. Rapid growth of oil imports into the U.S. started only in the early 1970s, with growing dependence on the Middle East and peaking at 30.2 qn Btu in 2005, just before the global financial crisis. In 2008, U.S. primary total energy exports started to rise markedly, with net energy imports turning negative in 2019, reaching 5.8 qn Btu in 2022 and marking the first time since 1953 that the country was a net exporter of primary energy. The U.S. is now the world's largest supplier of liquified natural gas, ahead of Qatar and Australia (U.S. Energy Information Administration, 2024b).

After peaking in 2005, U.S. net imports of crude oil and petroleum products declined, becoming negative around 2020. The country still imports crude oil (reflecting the capacity of domestic refiners to process crudes) but became a net exporter of petroleum products in 2010 and of natural gas in 2016. It has been a net exporter of coal and coal coke since at least 1950 (U.S. Energy Information Administration, 2024b). In 2022, total energy exports rose to the highest level ever recorded, 27.4 quadrillion Btus, representing a 9.3% increase over the previous year (*ibid.*).

Since the start of this Century, U.S. energy use and carbon emissions have consistently declined, whether measured in energy-related CO_2 emissions per capita or in the carbon intensity of either the energy supply or the economy (Figure 2). Two factors have interacted to reduce the carbon intensity of the economy (in mt CO_2 per 2012\$GDP) by about 45% between 2000 and 2021: On the one hand, the energy intensity of the economy (in Btu/2012\$GDP) has declined by about 34% – meaning the economy has become more carbon and energy efficient – and on the other the carbon intensity of the energy supply (in kg CO_2/mn Btu) has also declined, by about 16%, indicating that the production of a given amount of energy is associated with fewer carbon emissions. A large part of this is also due to rapid increases in the production of energy form renewable sources (+120% from 2000 to 2023), and despite rapid increases in crude oil (+120%) and natural gas production (100%).

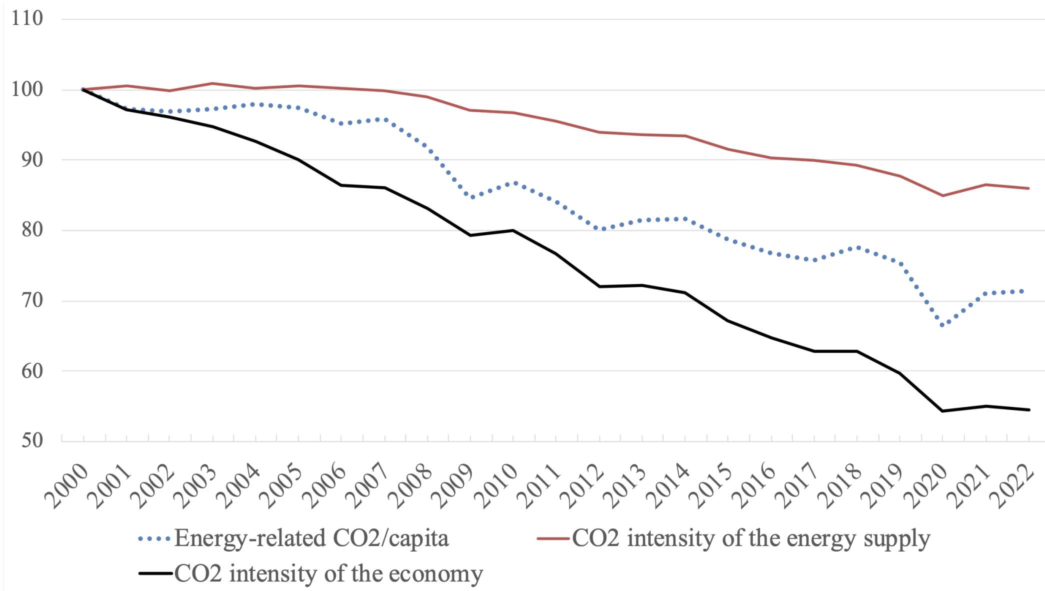
The sharp decline in carbon emissions during the Covid-19 pandemic was relatively short-lived, with manufacturing the first to rebound among the major sectors. In fact, the manufacturing sector emitted 200 mn. mt. more CO_2 in 2022 than in 2019, followed by electricity supply, other, agriculture, transport and households, according to the IMF.[3]

While total energy use (not shown in Figure 2) initially rose slightly, U.S. Greenhouse Gas (GHG) emissions were essentially flat through the middle of the first decade of the 21st Century, until 2007 or just before the Global Financial Crisis. During Covid-19 the CO_2 intensity of both the energy supply and of the economy declined, with a more pronounced drop for the latter (Figure 2). According to Feng et al. (2015) the patterns from about 1997

[2]EIA refers to the Energy Information Administration.

[3]https://www.imf.org/en/Blogs/Articles/2022/06/30/greenhouse-emissions-rise-to-record-erasing-drop-during-pandemic

Figure 2: U.S. Carbon Emissions and Energy Intensity, 2000-2022



Source: Author using EIA data. Data represent averages of the States. https://www.eia.gov/environment/emissions/state/

to 2007 can be attributed to growth in population and energy consumption, which were attenuated by changes in fuel mix (gas consumption rose by 8%) and reductions in energy intensity and consumption patterns as well as changes in production structure. The 5% decline in GHG emissions between 2020 and 2021 (U.S. Environmental Protection Agency, 2023) reflected not only a sharp collapse in economic activity that would usually accompany a recession, but also significant reductions in automobile pollution as working-from-home took hold especially in densely settled, metropolitan areas (e.g., Tao et al. (2023)). The rapid economic recovery following lockdowns is equally remarkable and can be traced to the American Recovery Act as well as related public stimulus programs.

2.2. State-Level Patterns

As of 2022, Texas (25.5% of the U.S. total, mostly natural gas and crude oil), Pennsylvania (10.1%), New Mexico (6.8%), Wyoming (6.1%) and West Virginia (5.9%) are the largest overall energy producers, including oil, gas, nuclear and renewable forms (Figure 3)[4]. Together these five States produced more than half (54%) of U.S. total energy. Pennsylvania joined this club only recently, after surging natural gas production started in 2009 due to fracking innovations (see Figure 3). Not surprisingly, the sources of energy used to generate electricity in the different States varied widely in 2021 (see Appendix Figure A1). For example, nuclear energy generation is prominent in the eastern States, except for Indiana, Kentucky and West Virginia as well as Vermont and Maine; coal is a more common fuel source in northern States not located on either coast; and patterns for natural gas are almost the inverse of those for nuclear energy – mostly in coastal States, including the Gulf

[4]https://www.eia.gov/state/seds/seds-data-complete.php?sid=US#Production Note the Figure is for 2021.

of Mexico. In terms of estimated total energy consumption, the top ranked State are Texas (14.5%), California (7.3%), Florida (4.6%), Louisiana (4.5%) and Pennsylvania (3.9%)[5].

The National Renewable Energy Lab (NREL) maps the suitability of different States in terms of solar and wind energy production:[6] the coasts and northern States are defined as wind energy zones, the center of the country as both solar and wind energy zones, while the eastern southern States and much of the West are solar energy zones. The Rocky Mountain States are also a geothermal energy zone. Among renewable fuels, production patterns largely follow the relative local abundance of the natural resource.[7] Hydropower is common among large rivers and the upper western States, while solar energy is important in the southwestern States with abundant sunshine, as well as in selected southeastern States (North Carolina and Georgia). Wind power, on the other hand is heavily concentrated in the windy Great Plains region of the nation's center, and in Maine. These differences in suitability are also evident in varying google search interest in terms such as "solar power" and "electric vehicles" across the states. These searches may also reflect past experiences with adverse effects of climate.

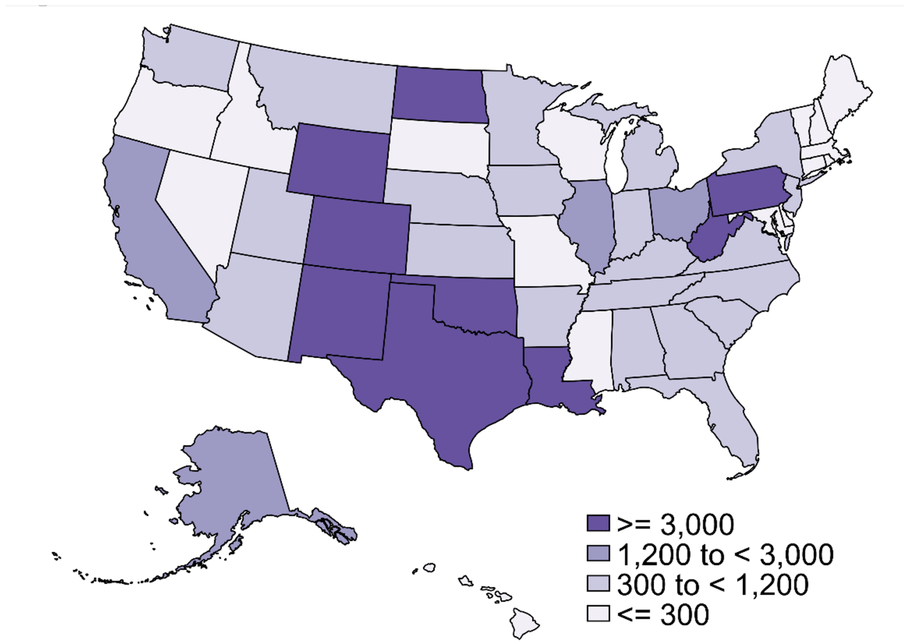
Alaska, Louisiana, North Dakota, Wyoming and Iowa consume the most energy per capita.[8] The Energy Information Administration (U.S. Energy Information Administration, 2023) notes that "states with relatively high-energy intensities tend to be in cold climates, are mostly rural, or have a large industrial base relative to their overall economies." This is evident in Figure 4. Wyoming and North Dakota (see commodity.com above) are both the biggest producers and, because energy production requires energy, also the biggest consumers of energy per capita. Coal remains the primary source of energy for both States.

Most States consumed more energy than they produced in 2022, with California, Florida, New York, Georgia, and Michigan, the top 5 importers, each importing 2,000 bn Btu or more.[9] Eleven States produced more energy than they consumed in 2022, led by Texas and followed by Pennsylvania, New Mexico, Wyoming and West Virginia which each produced a surplus of 4,900 or more tn Btu in 2022. Only Utah and Vermont are close to being self-sufficient, importing less than 100 tn Btu. Managing these energy flows is a classical regional science problem, where places of production and consumption differ, and a robust distribution system is needed. This also raises the question of where the various costs of pollution associated with energy production are incurred relative to the consumption sites, i.e., of the externalities imposed on energy producing areas (see below). Figure 4 shows net exports of energy (electricity) by State measured in mn of Watt hours, in 2023. The three largest exporters of this resource are Pennsylvania, Texas and Alabama. Virginia and Massachusetts are the biggest importers.

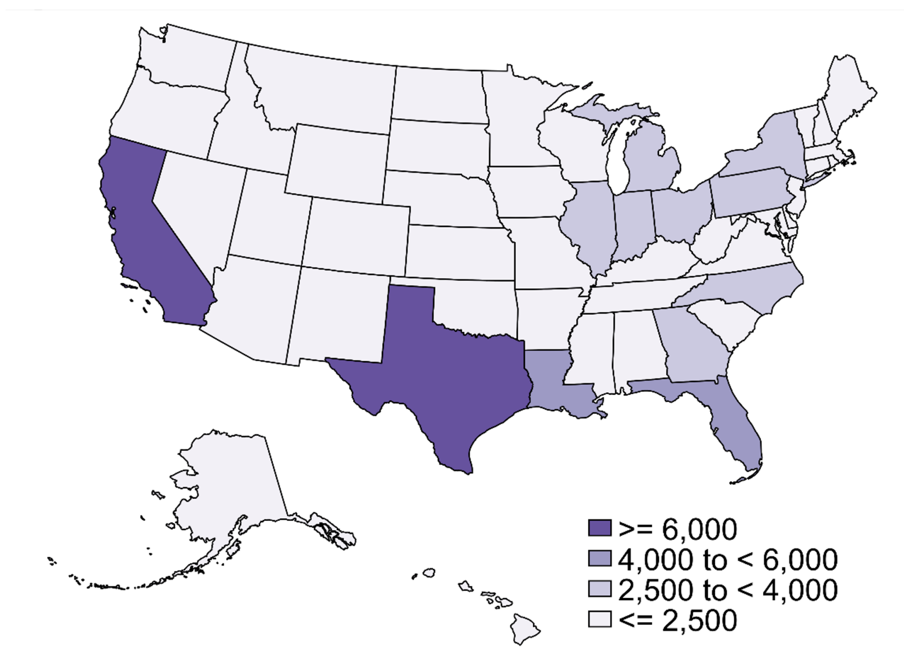
Last, Louisiana consumed the most energy per real dollar of GDP in 2022, with 18,360 Btu per chained (2017) dollar of GDP, and as such with the least energy efficient states. Others, in declining order, were Alaska, Wyoming, North Dakota, West Virginia and five

[5]https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_sum/html/rank_use_gdp.html&sid=US
[6]https://www.energy.gov/femp/renewable-energy-maps-and-tools
[7]See, for example, https://www.energy.gov/femp/renewable-energy-maps-and-tools
[8]https://www.eia.gov/state/rankings/?sid=US
[9]ttps://www.eia.gov/state/seds/sep_prod/pdf/P3.pdf U.S. EIA State Energy Data System 2022: Production, Table P3. https://www.eia.gov/state/seds/seds-data-complete.php#Production

Figure 3: State total energy production and consumption, 2021, trillion Btu



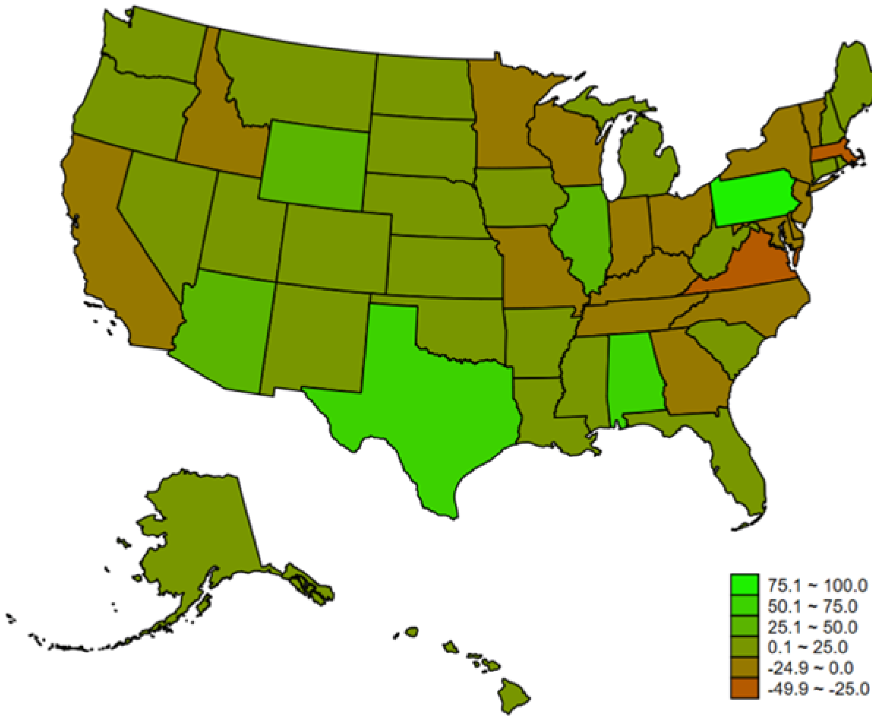
(a) Production



(b) Consumption

Source: EIA data and map.

Figure 4: Net Energy Exports by U.S. State, in million MWh, 2023



Source: Author using EIA data.

other States in the U.S. South.[10] Top-energy producing States Texas and Pennsylvania were ranked 13th and 26th. For Pennsylvania this points to important sectors in the economy that do not require large amounts of energy. The most energy efficient States, showing that the software and finance industries, among others, do not require large amounts of energy, are the District of Columbia with 980 Btu per dollar of GDP, New York, California, Massachusetts and Connecticut with 2,560 Btu per dollar of GDP. Of the top eleven most energy-efficient States, all but two are located in the Northeast U.S.

2.3. Greenhouse Gas Emissions (CO_2)

As already noted, carbon emissions have been declining since the beginning of the Century. Texas was by far the largest emitter of carbon dioxide emissions in 2022, with double the amount of California, the next highest emitter (663.0 compared with 326.2 million metric tons).[11] The next highest-emitting States were Florida, Pennsylvania, Ohio and Louisiana, each emitting 190 million Mt or more. On a per capita basis, on the other hand, Wyoming, South Dakota, Alaska, West Virginia and Louisiana emitted the most CO_2 of all States (Figure 5). Coal is West Virginia's primary energy source, while natural gas is the leading source for Alaska and Louisiana. New York, Massachusetts, California, Maryland and Ver-

[10]https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_sum/html/rank_use_gdp.html&sid=AL
[11]https://www.eia.gov/state/rankings//series/226; https://www.eia.gov/state/rankings/?sid=US/series/226

mont emit the least amount of CO_2 gases per capita of all states. Natural gas is the primary energy source for the three lowest emitters, while nuclear and hydroelectric energy play that role for the other two top five states.

Considering CO_2 emissions on a per square mile rather than a per capita basis produces a notably different image, on the other hand. The Great Plains states, including Wyoming and North Dakota as well as Alaska and even California, fare much better than the national average, but this is not the case for West Virginia and Louisiana. Especially noteworthy are the high-emissions southern New England States, as well as New Jersey, Maryland, Pennsylvania, Ohio and Indiana, which may be a legacy effect of the rustbelt economy,[12] and at least for DC, New York, New Jersey and Massachusetts is somewhat counter to the relatively high energy efficiency of these States.

3. ENERGY AND GROWTH

3.1. Economic growth and GHG emissions

The relationships between energy, pollution and GDP levels, and growth and well-being are important, with an important question being whether there is a trade-off between these variables (e.g., Goetz et al. (1996); Pagoulatos et al. (2004); Greenstone (2024)). One branch of this literature focuses on what is known as the environmental Kuznet's curve (e.g., Rupasingha et al. (2004), Ozcan et al. (2024)). At the level of nations, the amount of energy consumed is a key input into economic activity and economic growth; in fact, growth is not possible without energy, and sustained increases in growth in both energy demand and supply are essential especially in lower income economies (see e.g., Greenstone (2024)). This is illustrated by exponentially rising emissions from energy consumption and per capita GDP levels at the level of nations (*op. cit.*). In the U.S., states with a more carbon intensive economy at the beginning of the 21st Century also enjoyed faster real personal income growth over the ensuing two decades (Figure 6).

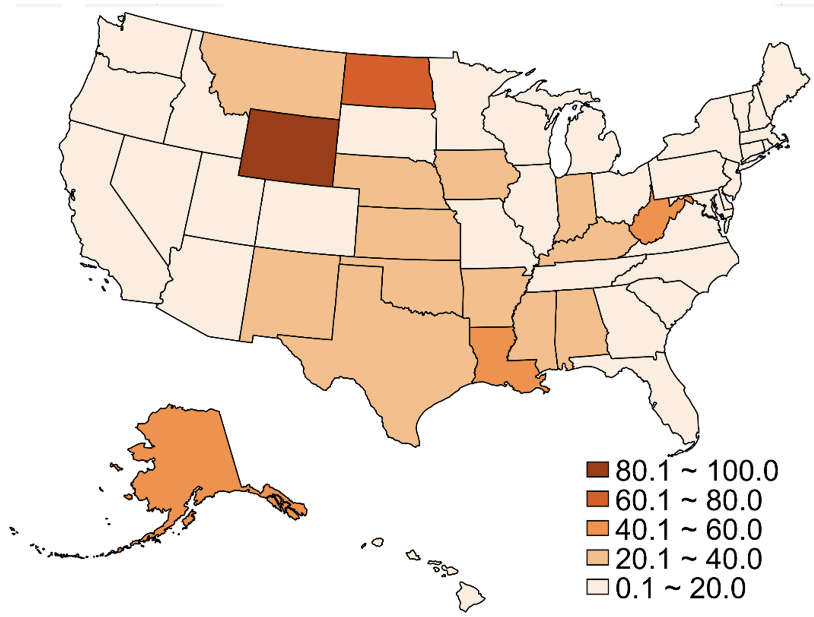
Over the period 2000-2021, Wyoming reduced its energy-related carbon emissions per capita by more than any other State, by 34 metric tonnes. This this was more than double the per capita reduction in Alaska, the next-highest State, followed by Indiana, West Virginia and Kentucky (U.S. Energy Information Administration (2024a), Table 4-10). A simple regression of the percent change (Δ) in real GDP per capita on percent changes in CO_2 emissions per capita from 2000 to 2022 shows a relatively weak but positive relationship with a simple correlation coefficient of 0.36 (R-square of 0.139):

$$\frac{\Delta \text{GDP}}{\text{capita}} = 0.44 + 0.53 \frac{\Delta \text{CO}_2}{\text{capita}}, \tag{1}$$

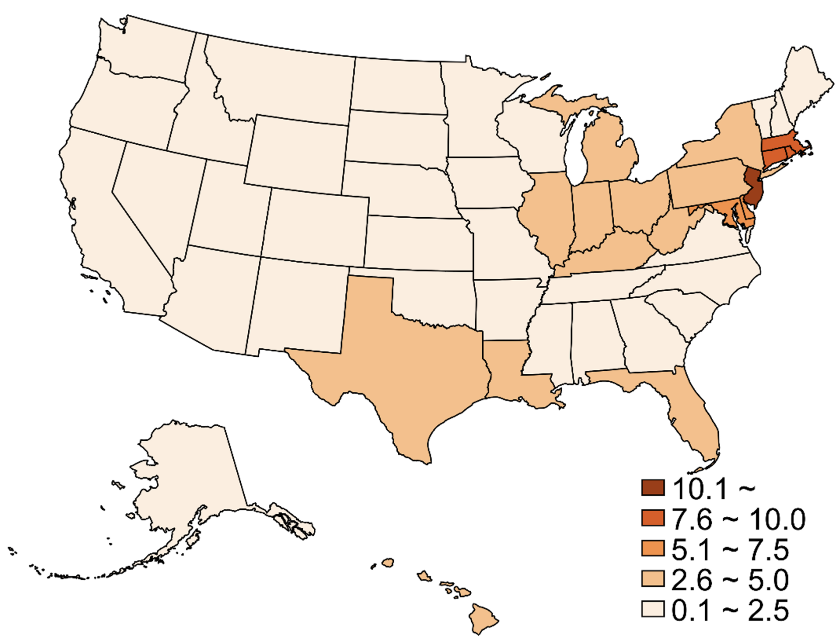
so that real GDP per capita growth was reduced by 5.3 percentage points for each 10% reduction in emissions per capita during this period. Alternatively, states that did not reduce their emissions by as much other states also grew more rapidly, indicating a trade-off between economic growth and GHG emissions.

[12] https://en.wikipedia.org/wiki/List_of_U.S._states_and_territories_by_carbon_dioxide_emissions

Figure 5: Total Carbon Dioxide Emissions, 2022



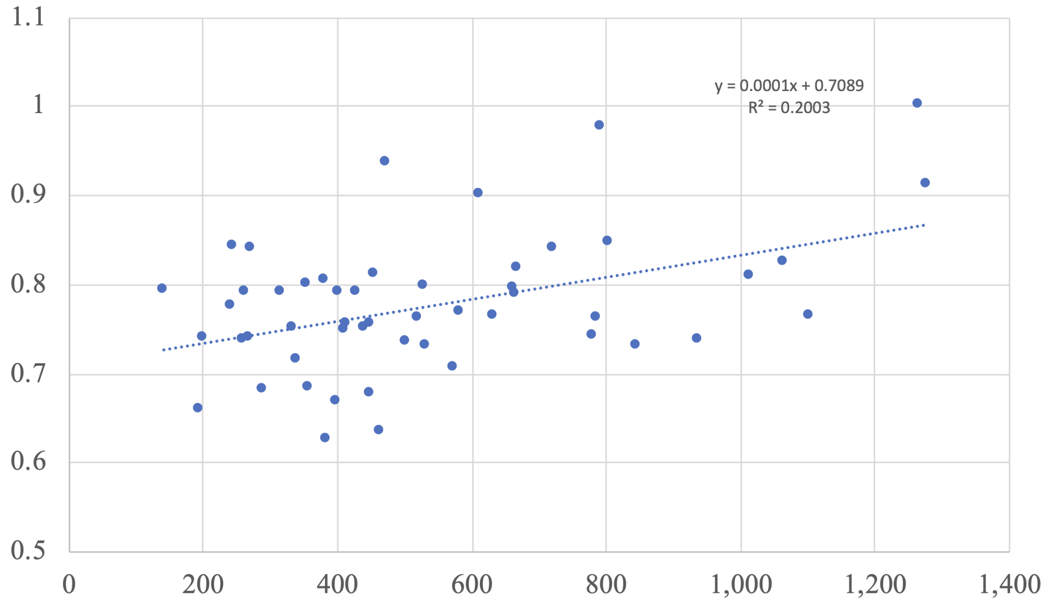
(a) CO2 per capita (ton)



(b) CO2 per 1,000 square miles (Mt)

Source: Author. Note: Data are in tonnes/capita and million tonnes/square mile.

Figure 6: Log income growth/capita 2000-2022 vs. 2000 carbon intensity of the economy



Source: Author using BEA (2024) and EIA (2024) data.

3.2. Energy and Well-being

The relationship between economic well-being and energy production and consumption as well as greenhouse gas emissions is complex and multi-facetted. In this paper two distinct literatures are briefly of interest. One relates to the effect of pollution associated with energy production or use on human health, and the other pertains to the local economic impacts of energy development. The former literature has deeper roots historically than the latter. Carleton et al. (2022) provide a long-term perspective on the effects of greenhouse gases on U.S. life expectancy over the years 1913-2017 using national level data. They find that CO_2, nitrous oxide and methane emissions have a contemporaneous (i.e., immediate) depressing effect on life expectancy, controlling for inequality and per capita GDP. Other work within the U.S. examines how exposure to higher $PM_{2.5}$ levels varies across ethnic and income groups. Jbaily et al. (2022) examine data for 32,000 zip codes between 2000 and 2016. In their spatial high-resolution study of a single state, Pennsylvania, which accounts for airborne spillovers of $PM_{2.5}$ pollution, Zhang et al. (2023) find that shale gas development caused 20 deaths over the period 2010-2017. Finally, a study across 40 nations, using subnational data on death rates and temperatures, seeks to value the effects on mortality of both adaptation costs and benefits of adapting to climate change Carleton et al. (2022). They estimate that the higher risk of dying, controlling for the benefits and costs of adaptation, will amount to 3.2% of global GDP by 2100.

A parallel literature focuses on the socioeconomic impacts of energy development, rather than pollution. For example, Rajbhandari et al. (2022) find that the existing skills and other human capital in a community determine the extent to which the local community benefits from oil and gas development, so that this kind of development may in turn encourage workers

Table 1: Simple convergence model for real GDP/capita, 2000-various years

Regressors	2019	2020	2021	2022
Constant	0.386***	0.353***	0.431***	0.486***
	(4.7)	(4.6)	(5.3)	(5.8)
gdp_{00} x 10^5	-.327*	-.361**	-.416**	-.493
	(1.99)	(2.2)	(2.4)	(2.8)***
Adj. R-square	0.059	0.079	0.094	0.125
F-statistic	3.33*	4.31**	4.52**	6.05**

Notes: N=48 contiguous states; t-statistics in parentheses; *=10%, **=5% and ***=1% l.o.s.

in or near energy towns to invest is such skills while also benefiting from such investments. In their nuanced analysis of coal mining and comparing the Appalachian region with the Western portions of the country, Betz et al. (2015) found subtle differences in impacts on workers and communities but no general existence of a resource curse. Last, Cho et al. (2022) find that states with energy related booms experienced higher rates of food security among children, particularly those living in households led by single mothers or parents with lower educational achievement. They attribute this directly to the energy-related boom in the state. Thus, even this highly cursory and selective review of the literature indicates the difficulty of drawing general conclusions about the net benefits and costs of resource booms in the U.S. This is confirmed by Brasier et al. (2011), who studied residents' perceptions early in Pennsylvania's shale boom.

3.3. Income Convergence

To conclude this section, and in preparation for the next, beta (β)-convergence in income growth is briefly examined for the period of interest. Ram (2021) finds no evidence of β-convergence in state-level per capita GDP growth over the years 1997-2018, and attributes this to a lack of capital flows to lower-income regions, thereby preventing convergence, which is in the spirit of Piketty (2017) work related to the relative returns to capital and labor. Table 1 reports the results of simple convergence models over the years 2000-2022, the most recent data available, and while this period is arbitrary, it is consistent with the focus of this paper (see also Appendix Figure A3). To evaluate the effect of Covid-19 on unconditional convergence, results are presented for 2019-2021 as well (Table 1). The regressions are of the form,

$$\ln(\frac{gdp_2 2}{gdp_0 0}) = \alpha + \beta gdp_0 0 + \gamma X_i 00 + \epsilon \tag{2}$$

where gdp is real (2017=100) GDP per capita with the subscript denoting the year, X is a set of regressors in the expanded, conditional estimation presented in Section 4, and the other letters refer to parameters to be estimated. The regression in the next Section also includes GHG emissions and political preferences as initial conditions.

The β-coefficient in Table 1 increases from 2019 to 2022 in real terms, and the goodness of fit also improves; this contrasts with the result reported in Ram (2021), for the period 1997-

2018. In terms of the business cycle, neither 1997 nor 2000 were recessionary periods, but a relatively short recession[13] was experienced from about May-December 2001, 2007-2008 during the global financial crisis, and again in February-March 2020 for a short duration and with the unemployment rate temporarily spiking at over 14%. Delaware started the 21st Century as the state with both the highest GDP/capita and the only state with a real economic decline in output. North Dakota started from a much lower GDP per capita in 2000 but also by far enjoyed the fastest growth in output over the period. West Virginia and Mississippi were at the bottom in terms of output per capita in 2000.

4. POLITICS AND ENERGY

4.1. Green Energy, Pollution and Voting Patterns

At some point before the turn of the last Century, climate change and renewable energy production became politically polarized. Figure 7 below indicates this polarization accelerated during the second Clinton-Gore term, in 1996, around the time when then-vice-President Gore started to promote the climate change agenda, and it continued with the first Bush-Cheney term in 2000. These increases in polarization can be illustrated in several ways. One is using the R-square value from successive regressions over time of the form:

$$Rep = a + b\ln(\mathrm{CO}_2) + e, \tag{3}$$

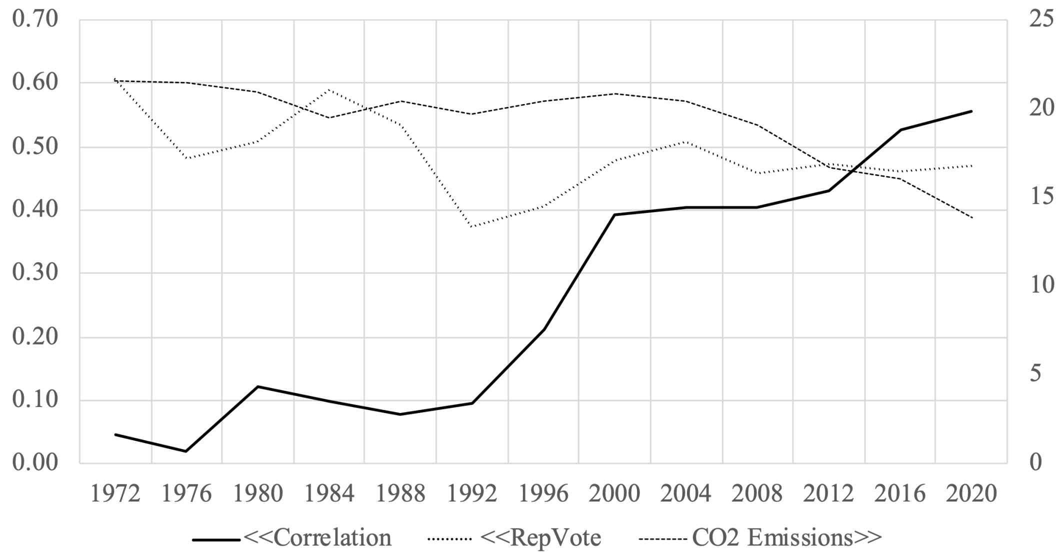
where *Rep* is the state's share of votes received by Republicans in the presidential elections and CO_2 is state-level carbon dioxide emissions per capita in metric tons. This R-square value has risen over time from less than 5% in the early 1970s to 55% in 2020, suggesting a strong correlation between CO_2 pollution levels and voting for the Republican candidate. The R-square values rose sharply during administrations led by Democrats: Carter-Mondale in 1976-1980; Clinton-Gore in 1992-2000; and in the second Obama-Biden term, 2012-2016.

Polarization of political preferences across red and blue states is also evident in the fact that clean-energy projects in 2024 under the Biden administration are heavily skewed towards states with Republican leanings. A New York Times analysis shows, and as also reported in the Economist magazine, about four-fifths of the $13 bn in Inflation Reduction Act investments were spent in Republican-voting districts as of Nov. 16th, 2024. At the same time, the correlation between republican voting shares and green energy use and generation, including among farmers in many red states, is negative but not significant statistically. For example, Iowa is a reliably Republican-voting State (casting 53% of votes for the Republican ticket in 2020) and uses green energy extensively (see Appendix Figure A2).

Google search trends show clear patterns in terms of interest among consumers in Electric Vehicles [automotive category] over time and across states. Search interest accelerated at the onset of Covid-19 in April 2020. The top ten States with the greatest search interest are mainly blue states, with a few red states mixed in: California, Hawaii, Washington, Oregon, Vermont, Colorado, Nevada, Arizona, Maryland, Utah, with Michigan coming in at No. 11. This is noteworthy because Detroit also has one of the lowest shares of EVs in new automobile registration.

[13] All recession data are from https://www.nber.org/research/business-cycle-dating

Figure 7: CO_2 Emissions/capita, Republican Vote Share and Correlations



Source: Author using data from U.S. EPA (2023a) and American Presidency Project (2024).

Data from S&P Global Mobility show the largest shares of EVs among all new cars being registered in metro areas are on the West Coast, starting with San Jose, CA (nearly 40%), San Francisco (33.5%) and Los Angeles (24.5%), as reported in Popovich (2024). California makes up six of the top ten states, and the West includes all ten. The first metro outside this region is Washington, DC, with 12.5%. The lowest shares are found in McAllen, TX (1.5%), Buffalo, N.Y. (2%) and Detroit, MI (3%). A recent study[14] by the Pew Research Center indicates that EV drivers tend to be younger, more affluent, urban residents and Democrat/democrat leaning. Furthermore, many buyers are "…motivated by environmental concerns, and some by interest in the latest, cutting-edge technology." Key concerns among rural motorists include the relative lack of density of EV charging stations, compared to the availability of gasoline.

4.2. Growing Challenges of Green Energy Development

With the expanding development of solar and wind energy, both the public news media and journal articles are describing problems associated with connecting new sites to the existing grid (e.g., Popovich and Plumer (2023); Osaka (2023)), and pushback against green energy development in the form of NIMBYism is expanding in several States (e.g., Weise and Bhat (2024)); this is also examined in emerging research on the effect of renewables development on housing values. Nilson et al. (2024) report "… $\tilde{1}/3$ of wind and solar siting applications… in the last five year were canceled, while about half experienced delays of 6+ months." Leading causes of cancelations were cited to be local ordinances or zoning; grid interconnection; and community opposition.

[14]htpps://www.pewresearch.org/short-reads/2023/07/13/how-americans-view-electric-vehicles/sr_2023-07-13_ev_1/

Lopez et al. (2023) show that the number of communities with zoning ordinances in the form of structure, road, property line or transmission setbacks increased sharply between 2018 and 2022, with over 1,853 counties having such an ordinance in 2022. For solar energy, 839 counties had some type of ordinance in 2022. With growing awareness among researchers of this pushback, early studies are showing the impacts of siting near such facilities on housing values, which are reminiscent of studies of land use disamenities two decades ago, such as CAFOs or toxic waste facilities (e.g., Ready and Abdalla (2004)). For example, Brunner et al. (2024) find that the values of homes one mile or closer to planned wind turbine facilities dropped by 11% compared to homes between 3 and 5 miles away. At the same time, find that these results do not extend to rural areas. Gou et al. (2024: abstract) write that "...wind turbine visibility negatively affects home values...in close proximity (¡5 miles/8 km). However, the effect diminishes over time and in distance and [disappears] for larger distances and toward the end of our sample."

As noted, (Davis et al., 2023), distribution is another growing challenge, which will be compounded by new energy-intensive users such as AI and related data centers as well crypto currency developers and, importantly expanding climate mandates pushing increased use of EVs that require a vast charging network. New data centers and chip manufacturing not only require vast amounts of energy but also need stable supplies which solar panels and wind turbines cannot deliver without extensive storage facilities. Thus, the decline in fossil fuel consumption may be unsustainable if it occurs too rapidly. Another conundrum is that distribution especially in Rocky Mountain states, which are well-endowed with wind and sunshine, the rugged topology raises the costs of distributing energy (Penney, 2021).

4.3. Politics, Carbon and Growth

To conclude this section, I examine the relationship between voting preferences, CO_2 emissions and economic growth early in the 21st Century with another simple regression model to answer the questions, have States that favored the Republican candidate in the 2000 presidential election grown more rapidly than other States, and are higher pollution levels associated with faster economic growth? According to Eqn [1] in Table2, there is no relationship among these variables. However, Eqn. [2] indicates that the interaction between voting and emissions does indicate marginally significant results: higher voting shares for the Republican candidate and higher levels of CO_2 pollution are both associated with slower economic growth. However, as either the voting share or the pollution increases, rising levels of the other variable are each associated with faster economic growth (i.e., the coefficient on the interaction term is positive and statistically significant).

5. CONCLUSION

The energy transition is occurring one firm and one household over time, and there is a great need for research in this area to understand barriers and constraints as well as impacts not only on these units but also on local communities as well as workers. Federal surveys such as the Manufacturing Energy Consumption Survey (MECS) and the Annual Business Survey (ABS) contain critical data, not previously examined in this context, at the level

Table 2: Expanded convergence model for real GDP/capita, 2000-2022

Regressors	[1]	[2]
Constant	0.324*	.0870***
	(1.72)	(2.83)
gdp_{00} x 10^5	-0.370*	-0.444**
	(1.72)	(2.13)
Rep. vote x 10^3	1.32	-7.93[15]
	(0.52)	(1.63)
CO_2/capita x 10^5	9.95	-14.64
	(0.73)	(2.02)
Rep. vote * CO_2/capita x 10^5		2.77**
		(2.19)
R-square	0.117	0.187
F-statistic	3.07**	3.71**

Notes: N=48 contiguous states; *=10%, **=5% and ***=1% l.o.s. (t-statistics)

of firms to address many of these issues. At the Northeast Center for Rural Development, we are examining these questions together with colleagues at the NSF and ERS through a NIFA-funded grant on decarbonization, which accesses and links the confidential firm-level data in the MECS and ABSs through a Federal Statistical Research Data Center (FSRDC).

In parallel, a new and important literature is emerging on the pushback or resistance to new developments, including more precise measures of economic impacts such as residential prices. More generally, it may be useful to frame the research and underlying debates as contributing to the "re-industrializing" of the Nation and to focus on specific distributional effects in different areas, especially those that are rural, given the inherently greater space requirements of many forms of renewable energy generation. More research is also warranted by regional economists on the economic and health impacts of the transition, as well as current and future workforce development needs along with opportunities for local supply chain development in the green energy economy.

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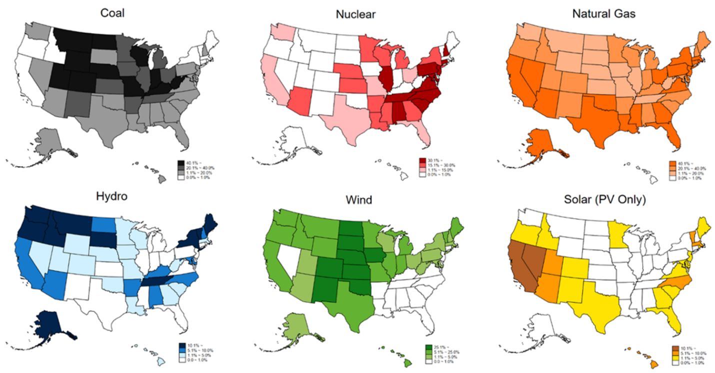
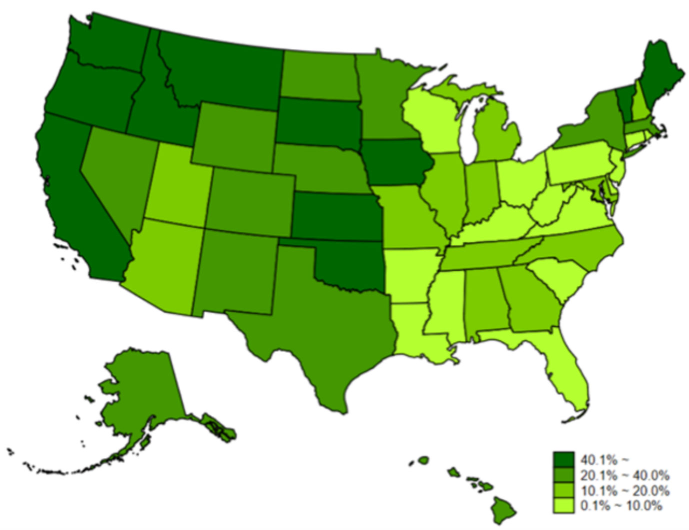
APPENDIX

Figure A1: Energy Sources by State (% of total used), 2021



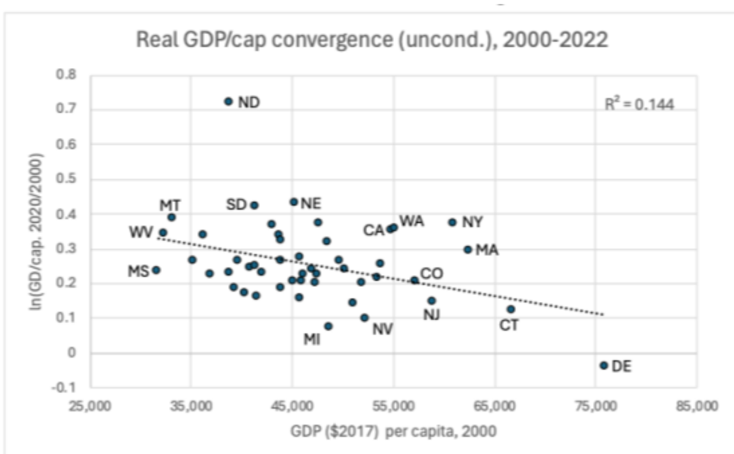
Source: Author using U.S. EIA and Nuclear Energy Institute Sources

Figure A2: Green Energy Sources as a percent of total



Source: Author using U.S. EIA and Nuclear Energy Institute Sources

Figure A3: Unconditional Income Convergence, 2000-2022



Source: Author using U.S. BEA Sources