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Exhibit No. 700

Consumers Council of Missouri – Exhibit 700
Jacqueline Hutchinson
Direct Testimony
File No. GR-2021-0108

Exhibit No: ________________
Issue(s):

- Gas Bill Affordability,
- Fixed Customer Charge,
- Late Fees,
- Protections for Low-Income and Medically Vulnerable Customers

Sponsoring Party: Consumers Council of Missouri

DIRECT TESTIMONY OF

JACQUELINE A. HUTCHINSON

Case No. GR-2021-0108

Filed: May 12, 2021

Q. PLEASE STATE YOUR NAME, OCCUPATION, AND BUSINESS ADDRESS.

My name is Jacqueline A. Hutchinson, and I am the Executive Director of the Consumers Council of Missouri.

Q. WHAT IS YOUR EDUCATIONAL BACKGROUND?

A. I have a BS degree in Business Administration from Washington University in St. Louis, and a MS degree in Urban Affairs and Policy Analysis, from Southern Illinois University in Edwardsville IL. Over my career, I have participated in numerous educational seminars and conferences focusing on utility issues and how those issues impact consumers, particularly vulnerable consumers.

Q. WHAT IS YOUR WORK EXPERIENCE?

A. My career spans more than forty years with Community Action Agencies (CAAs) in the state of Missouri, and Currently with Consumers Council of Missouri. I have been responsible for implementation of Federal, State and private donation fuel assistance and homeless prevention programs in the St. Louis area. Those programs include Low-Income Home Energy Assistance Programs (LIHEAP) and Community Services Block Grant (CSBG) programs in the St. Louis area.

I have also been actively involved in energy policy issues and advocacy for low-income consumers on a local, state, and national level for more than 30 years. I have provided testimony in almost every Missouri Public Service Commission

(“Commission” or “PSC”) general rate case impacting the St. Louis area since the 80’s.

Q. CAN YOU EXPLAIN MORE ABOUT YOUR EXPERTISE, AS IT RELATES TO THIS PSC MATTER?

A. Most notably my expertise includes the following:

Rate Case Interventions

My career has spanned for more than forty years with Community Action Agencies in Missouri, and as a Consumers Council of Missouri member. Over the years, I have provided testimony on behalf of low-income Missourians in most of the rate cases filed by utilities providing service in the St. Louis area.

Cold Weather Rule and Affordability Plans

I have provided testimony and/or been a part of negotiation of every Cold Weather Rule proceeding in Missouri, including the rulemaking case that initially created that rule. I have reviewed Percentage of Income Payment Plans (PIPPs), affordability plans with tiered credits, and low-income rates that have been proposed in other states and have recommended that the best of such plans be implemented through rate case proceedings in Missouri. I have participated in settlement negotiations with various utilities, worked with Commission Staff (Staff), the Office of the Public Counsel (OPC), and nonprofit advocates to develop viable low-income affordability programs, as well as programs that are designed to protect consumers that are vulnerable due to serious medical conditions.

Governor's Energy Policy Council

In 2003, I was appointed by the Governor as a member of this council. The initial focus of the Council was to prepare a state report focusing on three key areas: An analysis of Missouri's current and future energy supplies and demand and impact on low-income; An analysis of the impact on Missouri of standard market design rules proposed by the Federal Energy Regulatory Commission; and make recommendations for how Missouri state government may demonstrate leadership in energy efficiency.

The PSC Cold Weather Rule and Long-Term Energy Affordability

I was an appointed member of the Cold Weather Rule and Long-Term Energy Affordability Task Force set up in Case No. GW-2004-0452, and worked with this group to establish agreed upon modifications to the Cold Weather Rule in 2004 that provided additional protections to disabled and low-income families and set standards for low-income energy affordability programs.

Q. FOR WHOM ARE YOU PROVIDING TESIMONY IN THIS PROCEDURE?

The Consumers Council of Missouri (Consumers Council), a nonpartisan, nonprofit corporation that is dedicated to educating and empowering consumers statewide and to advocating for their interests. After serving several years as Board President, I assumed the role of Executive Director of the organization in 2020.

Q. WHAT TESTIMONY DO YOU OFFER IN THIS CASE?

A. Consumers Council of Missouri opposes the level of the rate increase requested by Spire, including various additional fees and surcharges that Spire proposes to increase. In the wake of the COIVD-19 pandemic, and the economic crisis which it has caused, any rate increase would increase the threat to the health and safety for many families already struggling to meet their basic needs. According to energy equity researcher, Dr. Tony G. Reames, the connection between energy affordability and public health is clear. He states, "A growing body of research suggests that access to affordable household energy is essential for maintaining good health. However, energy poverty (that is, insufficient wealth to provide adequate access to energy) is a distinct challenge that threatens a household's ability to adequately maintain those energy services." (International Journal of Environmental Research and Public Health, January 2021, Attachment JAH-2 to this testimony).

Q. WHAT ARE THE RECENT POVERTY AND ENERGY BURDEN STATISTICS IN MISSOURI?

A. The following facts should be given serious consideration and factor into the decisions that the Commission makes in this case. A just and reasonable result in this rate case should not create any unnecessary additional financial hardship for most consumers, and should particularly avoid unjustifiably burdening low-income and fix-income elderly households. The Commission should be mindful that many consumers live month to month, and cannot financially bear any further increases to their monthly budget.

The number of households facing unaffordable home energy burdens is staggering. According to the most recent five-year American Community Survey, nearly 145,000 Missouri households live with an income at or below 50% of the Federal Poverty Level (FPL) and face a home energy burden of 27%. And nearly 189,000 *additional* Missouri households live with incomes between 50% and 100% of the Federal Poverty Level and face a home energy burden of 14%. Energy burden reflects household expenditure on energy utilities relative to the household's gross income. (See Attachment JAH-1 to this testimony for more relevant statistics).

Missouri elderly and disabled residents have increased health risk to COVID-19, and any boost in their household utility costs dramatically increases the "heat or eat" decisions that many Missouri residents are already making at an alarming rate. Home energy is a crippling financial burden for low-income families.

According to Dr. Tony Reames:

The US Energy Information Administration estimates that one in three US households experience some form of energy poverty. Similarly, it also is important to further understand how this particular type of relative resource availability is connected to public health. Energy burden is one measure of energy poverty and a potentially important addition to the determinants of public health.". . . families that have trouble paying their energy bills may sacrifice nutrition, medicine, and other necessities in order to avoid shutoff." (Int. J. Environ. Res. Public Health January **2021**, pg 3)

Recent research has shown that low-income households and households of color spend less on energy overall, yet, they spend a higher proportion of income on energy, and they also spend more on energy per square foot of their domicile (Ibid., Reames Int. J. Environ. Res. Public Health **2021**, pg 3

In 2020, more than 69,000 Missouri households lived below 200% of the Federal Poverty Level. This number is likely to show a dramatic increase when 2021 data is available, when the impact of the pandemic is reflected.

The Home Energy Affordability Gap in Missouri exceeds 630 billion dollars. This gap is the difference between what customers can afford to pay and what they are actually billed. (HEAG Fact Sheet, Roger Colton)

Q. WHAT ARE YOUR RECOMMENDATIONS IN THIS CASE?

Low-income households pay an average of 46% of their gross income towards housing and energy costs. However, households at 50% of the Federal Poverty Guideline may pay up 54% of their income just on energy. Gas service is essential to public health, particularly during the long recovery from a pandemic. Consequently, Consumers Council makes the following recommendations:

1. Reduction in the fixed residential customer charge.
2. All of Spire's reconnect charges, collection trip charges, and punitive late fees should be eliminated.
3. The funding of the Spire Affordability Program should be increased and the program revised to better serve its purpose.

4. A transparent and easily accessible medical registry program should be created for Spire customers that have a chronic or serious medical condition, that provides heightened procedures to help prevent medical tragedies related to household disconnection from energy services.

Q. PLEASE EXPLAIN YOUR RECOMMENDATION RELATED TO THE FIXED CUSTOMER CHARGE.

A. Spire's current fixed residential customer charge is extremely high at $22.00. Fixed charges are regressive and hurt many of the elderly and those living at or below minimum wage. To promote affordability, rates should be based more on energy usage than on fixed amounts. If a consumer's gas delivery rates are based primarily on a volumetric measure, that consumer has a greater ability to lower their bills through energy conservation or energy efficiency measures. Consumers generally prefer the ability to control their bills, rather than unavoidable fixed fees.

Ideally, the rate design for residential customers should include a fixed charge that is based on no more costs than the meter, customer service, and the line to the dwelling. The new customer charge should be no higher than what those costs can support, or no higher than a fixed rate $16.00 per month.

Q. PLEASE EXPLAIN YOUR RECOMMENDATION RELATED TO SPIRE'S RECONNECT CHARGES, COLLECTION TRIP CHARGES, AND LATE FEES.

A. I believe that all of Spire's reconnect charges, collection trip charges, and late fees should be eliminated. Spire has not shown a cost-based justification for these fees, nor provided sufficient evidence that these fees provide the "deterrence" to nonpayment that it desires. From my experience, these fees do not change behavior, rather they merely create an inequitable cost of service for struggling customers, who are likely to have high energy burden and inability to cover their current bills, much less extra fees.

Q. PLEASE EXPLAIN YOUR RECOMMENDATION RELATED THE SPIRE AFFORDABILITY PROGRAM.

The Spire Affordability Program has overall been a positive program as a pilot, although it suffers from a lack of proper funding and it would benefit from some revisions in its design. At a minimum, I recommend that the annual funding for this program should be increased fifty percent, ideally with some cost sharing from the utility's shareholders.

I also recommend that the eligibility for receiving the benefits of this program should be increased to 250% of the federal poverty level. This is the eligibility level that many low-income energy programs have adopted around the country.

Program design should include with collaboration with interested intervenors and agencies providing utility assistance in Spire service areas. I believe that several best practices can be borrowed from the successful Keeping Current Program of Ameren Missouri. Program details are outlined in the Ameren Program Design Study, an independent study performed by APRISE, Inc. This affordability program should strive to provide equitable access, and be available to customers who do not necessarily receive LIHEAP assistance.

I also recommend an independent outside review of the past Spire affordability program, with design improvement recommendations. To further more informed policy discussions, I believe that Spire should be ordered to track and report energy burden data, number of cut-offs, collection actions and other data in a public manner that can be assessed by all interested parties.

Q. WHAT DID THE INDEPENDENT STUDY OF THE AMEREN MISSOURI "KEEPING CURRENT" PROGRAM SHOW?

A. The most recent study of that program stated the following:

> A 2019 summary of Impacts for The Ameren Keeping Current Program showed positive impacts for customers who maintained service for a year after enrollment:
>
> 1. Affordability – The program has improved affordability, but participants still face high energy burdens. Electric heat participants had their energy burdens decline from a mean of 27 percent in the year prior to enrollment to 22 percent in the year following enrollment. While this is a significant decline, it still represents an unaffordable energy bill. Alternative Heat participants had their mean energy burden decline from 22 percent to 19 percent. About 56 percent had an energy burden over ten percent while participating in Keeping Current.
>
> 2. Bill Payment – The program had positive impacts on payment regularity and bill coverage rates for the year-round participants. The impact analysis found that customers improved their payment regularity and covered a greater percentage of their bills. Electric Heat participants averaged eight payments in the pre-enrollment period and had a net increase of one payment following enrollment. Alternative Heat participants averaged about eight payments in the pre-enrollment period and had a net increase of about two payments following enrollment. Electric Heat participants had a net increase in total coverage rate of seven percentage points and Alternative Heat participants had a net increase of 18 percentage points
>
> 3. Energy Assistance – Participants were less likely to receive LIHEAP than they were prior to Keeping Current participation. Agency caseworkers should be encouraged to provide more assistance to participants with program applications. Electric Heat and Alternative Heat participants were less likely to receive LIHEAP assistance in the post-enrollment period. While 54 percent of Electric Heat participants received LIHEAP in the pre-enrollment period, 47 percent received it in the post period, a six-percentage point net reduction. Alternative Heat participants also experienced a reduction. This is problematic, as agencies should be working with

participants to ensure that they apply for LIHEAP following Keeping Current enrollment.

4. Collections Impacts – The program has resulted in reduced collections actions and service terminations. Participants had a large net reduction in disconnect notices, service terminations, and payment arrangements following the program enrollment. While service terminations declined by 24 percent points for Electric Heat participants, payment arrangements declined by 35 percentage points for Alternative Heat participants."

(2019 APRISE, Inc. Ameren Impact Study)

Q. WHAT IS YOUR REOCMMENDATION REGARDING A MEDICAL REGISTRY PROGRAM?

A. A transparent and easily accessible medical registry program should be created for Spire customers that have a chronic or serious medical condition, that provides heightened procedures to help prevent medical tragedies related to household disconnection from energy services.

Currently, it is unclear to the public how a gas customer can be placed on a list of households with a medically vulnerable resident. The utility should have an online portal that is accessible to medical health professionals who can place customers on the list of those that need special attention, due to the serious medical harm that could occur should that household be disconnected from energy service.

Q. WHAT OTHER RECOMMENDATIONS DO YOU SUGGEST TO SUPPORT AFFORDABILITY OF NATURAL GAS RATES?

A. I recommend an increase in energy efficiency funding. Funds should target homes with high energy burdens that need measures above and beyond those that government agencies are able to cover with federal weatherization dollars, or those who do not quite qualify for those funds. Energy efficiency can offer a long-term solution to some high energy burdens. It helps households reduce their energy usage, thus lowing energy bills and also improving home health, comfort, and safety. Efficiency programs targeting low-income households are well suited to addressing high energy burdens. Some best practices for increasing energy efficiency and energy affordability for low-income and energy-burdened households can be found in “Understanding Energy Burden” (ACEEE 2019).

Q. DOES THAT CONCLUDE YOUR TESTIMONY?

Yes.

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

In the Matter of Spire Missouri Inc.'s d/b/a Spire Request for Authority to Implement a General Rate Increase for Natural Gas Service Provided in the Company's Missouri Service Areas.	)))))	**File No. GR-2021-0108**

AFFIDAVIT OF JACQUELINE A. HUTCHINSON

I, the undersigned, being duly sworn, states that my name is Jacqueline A. Hutchinson and that the foregoing Direct Testimony of Jacqueline A. Hutchinson, including attachments, was prepared by me on behalf of the Consumers Council of Missouri. This testimony was prepared in written form for the purpose of its introduction into evidence in the above utility case at the Missouri Public Service Commission.

I hereby swear and affirm that the attached testimony is true and correct to my best knowledge, information, and belief, and I adopt said testimony as if it were given under oath in a formal hearing.

Jacqueline A. Hutchinson

Subscribed before me on this 12th day of May, 2021:

SHERON L. DOUGLAS
Notary Public, Notary Seal
State of Missouri
St. Louis County
Commission # 13693260
My Commission Expires 10-27-2021

Attachment JAH - 1

MISSOURI

THE HOME ENERGY AFFORDABILITY GAP 2020

(2ND SERIES) PUBLISHED APRIL 2021

Finding #1

Poverty Level	Home Energy Burden
Below 50%	27%
50 – 100%	14%
100 – 125%	10%
125 – 150%	8%
150 – 185%	6%
185% - 200%	6%

Home energy is a crippling financial burden for low-income Missouri households. Missouri households with incomes of below 50% of the Federal Poverty Level pay 27% of their annual income simply for their home energy bills.

Home energy unaffordability, however, is not only the province of the very poor. Bills for households with incomes between 150% and 185% of Poverty take up 6% of income. Missouri households with incomes between 185% and 200% of the Federal Poverty Level have energy bills equal to 6% of income.

Finding #2

Poverty Level	Number of Households	
	Last Year	This Year
Below 50%	149,010	144,545
50 – 100%	194,224	188,708
100 – 125%	112,698	110,407
125 – 150%	107,477	106,824
150 – 185%	161,949	160,114
185% - 200%	68,485	68,988
Total < 200%	793,843	779,586

The number of households facing unaffordable home energy burdens is staggering. According to the most recent five-year American Community Survey, nearly 145,000 Missouri households live with income at or below 50% of the Federal Poverty Level and face a home energy burden of 27%. And nearly 189,000 *additional* Missouri households live with incomes between 50% and 100% of the Federal Poverty Level and face a home energy burden of 14%.

In 2020 the total number of Missouri households below 200% of the Federal Poverty Level stayed relatively constant from the prior year.

Finding #3

Home Energy Affordability Gap: 2011 (base year)	$665,722,385	
Home Energy Affordability Gap: 2020 (current year)	$630,134,966	
Home Energy Affordability Gap Index (2011 = 100)	94.7	

The Home Energy Affordability Gap Index (2nd Series) indicates the extent to which the Home Energy Affordability Gap has increased between the base year and the current year. In Missouri, this Index was 94.7 for 2020.

The Home Energy Affordability Gap Index (2nd Series) uses the year 2011 as its base year. The Index for 2011 is set equal to 100. A current year Index of more than 100 thus indicates that the Home Energy Affordability Gap for has increased since 2011. A current year Index of less than 100 indicates that the Home Energy Affordability Gap has decreased since 2011.

Finding #4

	Last Year	This Year
Gross LIHEAP Allocation ($000's)	$80,217	$74,048
Number of Households <150% FPL	563,409	550,484
Heating/Cooling Bills "Covered" by LIHEAP	99,648	94,570

Existing sources of energy assistance do not adequately address the Home Energy Affordability Gap in Missouri. LIHEAP is the federal fuel assistance program designed to help pay low-income heating and cooling bills. The gross LIHEAP allocation to Missouri was $74.0 million in 2020 and the number of average annual low-income heating and cooling bills "covered" by LIHEAP was 94,570.

In comparison, the gross LIHEAP allocation to Missouri in 2019 reached $80.2 million and covered 99,648 average annual bills.

Finding #5

Primary Heating Fuel	Penetration by Tenure	
	Owner	Renter
Electricity	29%	50%
Natural gas	54%	43%
Fuel Oil	0%	0%
Propane	11%	5%
All other	6%	2%
Total	100%	100%

The Home Energy Affordability Gap in Missouri is not solely a function of household incomes and fuel prices. It is also affected by the extent to which low-income households use each fuel. All other things equal, the Affordability Gap will be greater in areas where more households use more expensive fuels.

In 2020, the primary heating fuel for Missouri homeowners was Natural Gas (54% of homeowners). The primary heating fuel for Missouri renters was Electricity (50% of renters).

Changes in the prices of home energy fuels over time are presented in Finding #6 below.

Finding #6

Fuel	2018 Price	2019 Price	2020 Price
Natural gas heating (ccf)	$0.899	$0.892	$0.867
Electric heating (kWh)	$0.103	$0.096	$0.098
Propane heating (gallon)	$2.030	$1.869	$1.646
Fuel Oil heating (gallon)	$2.902	$2.657	$2.626
Electric cooling (kWh)	$0.133	$0.134	$0.130

In Missouri, natural gas prices stayed relatively constant during the 2019/2020 winter heating season. Fuel oil prices stayed relatively constant and propane prices fell 11.9%.

Heating season electric prices stayed relatively constant in the same period and cooling season electric prices stayed relatively constant.

Home Energy Affordability Gap Dashboard -- Missouri 2020 versus 2019

<table>
<tr><td>AVERAGE DOLLAR AMOUNT
BY WHICH ACTUAL HOME ENERGY BILLS
EXCEEDED AFFORDABLE HOME ENERGY BILLS
FOR HOUSEHOLDS BELOW 200% OF POVERTY LEVEL.

2019: $879 per household

2020: $808 PER HOUSEHOLD</td><td>AVERAGE TOTAL HOME ENERGY
BURDEN FOR HOUSEHOLDS BELOW 50%
OF POVERTY LEVEL.

2019: 28% of household income

2020: 27% OF HOUSEHOLD INCOME</td></tr>
<tr><td>PERCENT OF INDIVIDUALS BELOW
100% OF POVERTY LEVEL.

2019: 14% of all individuals

2020: 14% OF ALL INDIVIDUALS</td><td>NUMBER OF AVERAGE LOW-INCOME HEATING/COOLING
BILLS COVERED BY
FEDERAL HOME ENERGY ASSISTANCE.

2019: 99,648 bills covered

2020: 94,570 BILLS COVERED</td></tr>
<tr><td colspan="2">PRIMARY HEATING FUEL (2020):

HOMEOWNERS - NATURAL GAS *** TENANTS - ELECTRICITY</td></tr>
</table>

NOTES AND EXPLANATIONS

The 2012 Home Energy Affordability Gap, published in May 2013, introduced the 2nd Series of the annual Affordability Gap analysis. The 2012 Home Energy Affordability Gap going forward cannot be directly compared to the Affordability Gap (1st Series) for 2011 and earlier years. While remaining fundamentally the same, several improvements have been introduced in both data and methodology in the Affordability Gap (2nd Series).

The most fundamental change in the Home Energy Affordability Gap (2nd Series) is the move to a use of the American Community Survey (ACS) (5-year data) as the source of foundational demographic data. The Affordability Gap (1st Series) relied on the 2000 Census as its source of demographic data. The ACS (5-year data) offers several advantages compared to the Decennial Census. While year-to-year changes are smoothed out through use of 5-year averages, the ACS nonetheless is updated on an annual basis. As a result, numerous demographic inputs into the Affordability Gap (2nd Series) will reflect year-to-year changes on a county-by-county basis, including:

- The distribution of heating fuels by tenure;
- The average household size by tenure;
- The number of rooms per housing unit by tenure;
- The distribution of owner/renter status;
- The distribution of household size;
- The distribution of households by ratio of income to Poverty Level;

Data on housing unit size (both heated square feet and cooled square feet) is no longer calculated based on the number of rooms. Instead, Energy Information Administration/Department of Energy (EIA/DOE) data on square feet of heated and cooled living space per household member is used beginning with the Home Energy Affordability Gap (2nd Series). A distinction is now made between heated living space and cooled living space, rather than using total living space.

The change resulting in perhaps the greatest dollar difference in the aggregate and average Affordability Gap for each state is a change in the treatment of income for households with income at or below 50% of the Federal Poverty Level. In recent years, it has become more evident that income for households with income below 50% of Poverty Level is not normally distributed. Rather than using the mid-point of the Poverty range (i.e., 25% of Poverty Level) to determine income for these households, income is set somewhat higher (40% of Poverty). By setting income higher, both the average and aggregate Affordability Gap results not only for that Poverty range, but also for the state as a whole, will be lower. The Affordability Gap results for other Poverty ranges remain unaffected by this change.

Another change affecting both the aggregate and average Affordability Gap is a change in the definition of "low-income." The Home Energy Affordability Gap (2nd Series) has increased the definition of "low-income" to 200% of the Federal Poverty Level (up from 185% of Poverty). While this change may increase the aggregate Affordability Gap, it is likely to decrease the average Affordability Gap. Since more households are added to the analysis, the aggregate is likely to increase, but since the contribution of each additional household is less than the contributions of households with lower incomes, the overall average will most likely decrease.

Most of the Home Energy Affordability Gap calculation remains the same. All references to "states" include the District of Columbia as a "state." Low-income home energy bills are calculated in a two-step process: First, low-income energy consumption is calculated for the following end-uses: (1) space heating; (2) space cooling; (3) domestic hot water; and (4) electric appliances (including lighting and refrigeration). All space cooling and appliance consumption is assumed to involve only electricity. Second, usage is multiplied by a price per unit of energy by fuel type and end use by time of year. The price of electricity, for example, used for space cooling (cooling months), space heating (heating months), and appliances (total year) differs to account for the time of year in which the consumption is incurred.

Each state's Home Energy Affordability Gap is calculated on a county-by-county basis. Once total energy bills are determined for each county, each county is weighted by the percentage of persons at or below 200% of the Federal Poverty Level to the total statewide population at or below 200% of the Federal Poverty Level to derive a statewide result. Bills are calculated by end-use and summed before county weighting.

LIHEAP comparisons use gross allotments from annual baseline LIHEAP appropriations as reported by the federal LIHEAP office. They do not reflect supplemental appropriations or the release of LIHEAP "emergency" funds. The number of average heating/cooling bills covered by each state's LIHEAP allocation is determined by dividing the total base LIHEAP allocation for each state by the average heating/cooling bill in that state, the calculation of which is explained below. No dollars are set aside for administration; nor are Tribal set-asides considered.

State financial resources and utility-specific rate discounts are not considered in the calculation of the Affordability Gap. Rather, such funding should be considered available to fill the Affordability Gap. While the effect in any given state may perhaps seem to be the same, experience shows there to be an insufficiently authoritative source of state-by-state data, comprehensively updated on an annual basis, to be used as an input into the annual Affordability Gap calculation.

Energy bills are a function of the following primary factors:

- Tenure of household (owner/renter)
- Housing unit size (by tenure)
- Heating Degree Days (HDDs) and Cooling Degree Days (CDDs)
- Housing size (by tenure)
- Heating fuel mix (by tenure)
- Energy use intensities (by fuel and end use)

Bills are estimated using the U.S. Department of Energy's "energy intensities" published in the DOE's Residential Energy Consumption Survey (RECS). The energy intensities used for each state are those published for the Census Division in which the state is located. Heating Degree Days (HDDs) and Cooling Degree Days (CDDs) are obtained from the National Weather Service's Climate Prediction Center on a county-by-county basis for the entire country.

End-use consumption by fuel is multiplied by fuel-specific price data to derive annual bills. State price data for each end-use is obtained from the Energy Information Administration's (EIA) fuel-specific price reports (e.g., Natural Gas Monthly, Electric Power Monthly). State-specific data on fuel oil and kerosene is not available for all states. For those states in which these bulk fuels have insufficient penetration for state-specific prices to be published, prices from the Petroleum Administration for Defense Districts (PADD) of which the state is a part are used.

The Home Energy Affordability Gap Index (2nd Series) uses 2011 as its base year. The base year (2011) Index has been set equal to 100. A current year Index of more than 100 thus indicates that the Home Energy Affordability Gap has increased since 2011. A current year Index of less than 100 indicates that the Affordability Gap has decreased since 2011. The Affordability Gap Index was, in other words, re-set in 2011. The Affordability Gap Index (2nd Series) for 2012 and beyond cannot be compared to the Affordability Gap Index (1st Series) for 2011 and before.

The Home Energy Affordability Gap is a function of many variables, annual changes in which are now tracked for nearly all of them. For example, all other things equal: increases in income would result in decreases in the Affordability Gap; increases in relative penetrations of high-cost fuels would result in an increase in the Gap; increases in amount of heated or cooled square feet of living space would result in an increase in the Gap. Not all variables will result in a change in the Affordability Gap in the same direction. The annual Affordability Gap Index allows the reader to determine the net cumulative impact of these variables, but not the impact of individual variables.

Since the Affordability Gap is calculated assuming normal Heating Degree Days (HDDs) and Cooling Degree Days (CDDs), annual changes in weather do not have an impact on the Affordability Gap or on the Affordability Gap Index.

Price data for the various fuels underlying the calculation of the Home Energy Affordability Gap (2nd Series) was used from the following time periods:

Heating prices	
Natural gas	February 2020
Fuel oil ***	Week of 02/10/2020
Liquefied petroleum gas (LPG) ***	Week of 02/10/2020
Electricity	February 2020
Cooling prices	August 2020
Non-heating prices	
Natural gas	May 2020
Fuel oil ***	Week of 10/05/2020
Liquefied petroleum gas (LPG) ***	Week of 10/05/2020
Electricity	May 2020

*****Monthly bulk fuel prices are no longer published. Weekly bulk fuel prices are published during the heating months (October through March). The prices used are taken from the weeks most reflective of the end-uses to which they are to be applied. Prices from the middle of February best reflect heating season prices. Bulk fuel prices from October best reflect non-heating season prices.**

Attachment JAH - 2

International Journal of
Environmental Research and Public Health

Article

Exploring the Nexus of Energy Burden, Social Capital, and Environmental Quality in Shaping Health in US Counties

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Abstract: The United States spends more on health care than any other OECD country, yet the nation's health is declining. Recent research has identified multiple sources for this decline, including one's position in social and economic structures, environmental quality, and individual and collective social capital. This paper assesses the primary hypotheses that the health effects of household energy burden, social capital and environmental quality on aggregated community health levels remain while controlling for other determinants. The analysis moves beyond prior research by integrating multiple secondary data sources to assess those effects across US counties. Three indicators of public health are analyzed (premature mortality, self-reported health, and life expectancy). The county-level energy burden is measured by the percent of household income spent on housing energy bills for low- and moderate-income households. In addition to energy burden, social capital, environmental quality and other determinants are included in the analysis. The results produced by multivariate regression models support the primary hypotheses, even while a number of control variables also have a significant effect on health. The paper concludes that public health is associated with a complex nexus of factors, including environmental quality and social capital, and that energy burden needs to be among the considerations.

Keywords: energy burden; social capital; environmental quality; public health; social determinants of health

check for updates

Citation: Reames, T.G.; Daley, D.M.; Pierce, J.C. Exploring the Nexus of Energy Burden, Social Capital, and Environmental Quality in Shaping Health in US Counties. *Int. J. Environ. Res. Public Health* **2021**, *18*, 620. https://doi.org/10.3390/ijerph18020620

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1. Introduction

The United States spends more on health care than any other OECD country. Despite this spending, many health outcomes are moving in the wrong direction. Life expectancy is declining, and chronic diseases, suicide rates, and other negative health outcomes are increasing [1]. Researchers and practitioners alike acknowledge the multitude of factors that determine health [2–4]. While access to and quality of health care is important, particularly if someone is ill, broader social, economic, and environmental factors also combine in ways to profoundly shape health and well-being across the life course [5,6]. This paper relies upon insights from the Social Determinants of Health (SDoH) framework as a context within which to better understand how a range of structural factors influence public health in US Counties. Figure 1 outlines the contours of this approach to understanding health. In this conceptual framework, health behaviors and clinical care contribute to public health, but notably, social, economic, and environmental factors also are important explanations for health outcomes across populations.

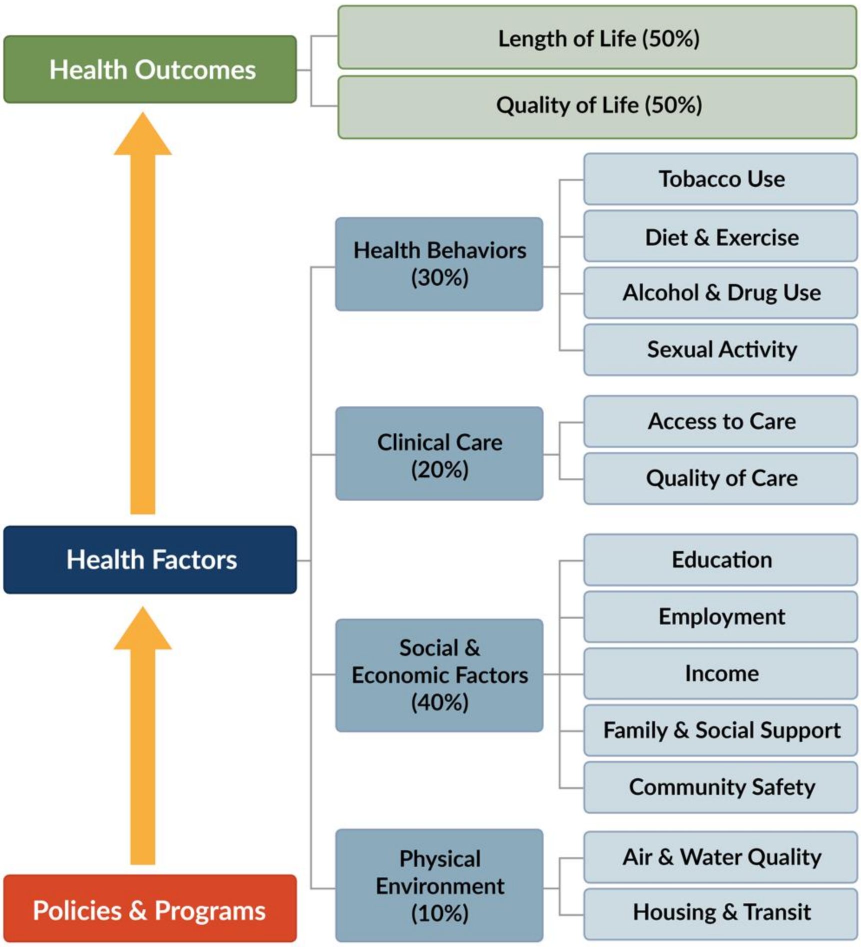

Figure 1. The conceptual framework outlining the social determinants of population health [7]. Country Health Rankings model ©2014 UWPHI.

While there has been considerable research conducted in order to better understand the social determinants of health, more work is needed to further identify how multiple, overlapping determinants may shape that health. This paper examines three different health outcomes in US counties: age-adjusted premature mortality, self-reported health, and life expectancy. Comparing patterns of determinants across these three outcomes helps to identify consistent and critical factors that shape public health. In particular, in addition to social determinants, this research examines the impact of energy burden, social capital, and environmental quality on all three health outcomes.

1.1. Energy Burden and Health

Prior research underscores the important relationship between wealth (to which energy burden is linked)—or lack thereof—and health [8–10]. A growing body of research suggests that access to affordable household energy is essential for maintaining good health [11,12]. However, energy poverty (that is, insufficient wealth to provide adequate access to energy) is a distinct challenge that threatens a household's ability to adequately maintain those energy services. The US Energy Information Administration estimates that one in three US households experience some form of energy poverty [13]. Similarly, it also is important to further understand how this particular type of relative resource availability is connected to public health. Energy burden is one measure of energy poverty and a potentially important addition to the determinants of public health [14–17]. Energy burden reflects household expenditure on energy utilities relative to the household's gross income capacity [18]. Disproportionate distributions of energy burden (both positive and negative) are evident in particular positions in social and economic systems, such as wealth, education, race or ethnic origin.

Recent research has shown that low income households and households of color spend less on energy overall, yet, they spend a higher proportion of income on energy, and they also spend more on energy per square foot of their domicile [19]. Relative to the concern of this paper, families that have trouble paying their energy bills may sacrifice nutrition, medicine, and other necessities in order to avoid shutoff. More than 25 million US households reduce or forgo food or medicine in order to pay energy costs [13]. Additionally, nearly 13 million US households experience leaving their homes at unhealthy temperatures [13]. Living in underheated homes puts adolescents at double the risk of respiratory problems and at five times the risk of mental health problems [20]. Furthermore, " ... living in homes that are not properly heated or cooled increases cases of asthma, respiratory problems, heart disease, arthritis, and rheumatism" [13,21–24]. Analyzing how energy burden, as an economic stressor, impacts health is important in that it can inform policy interventions that may improve public health.

1.2. Social Capital and Health

Social capital—the individual and collective resource that emanates from trust and reciprocity-based networks—is one of the most frequently identified sources of variation in public health [25]. Indeed, community social capital is an established and important determinant of health and well-being [25–35]. Social capital has been shown to have broad-based impacts on public health levels even in the context of other forces that effect health, namely economic stress and socio-demographic variables, such as income and education [36]. The networks providing social capital offer mutual support, opportunities for collaboration and an avenue for health-related activities and information that can enhance well-being. Higher levels of social capital are consistently linked to positive health outcomes; this relationship holds hold across a range of health outcomes regardless of how social capital is measured [37–43].

1.3. Environmental Quality and Health

Past research indicates that environmental quality also is linked to health. Decades of research have firmly established that environmental quality is a consistent determinant of health and that environmental quality is a major concern for both public health officials and the general public in the US. [44–46]. An extensive body of research has demonstrated the adverse health outcomes associated with poor environmental quality (in particular, air pollution exposure, specifically $PM_{2.5}$ or particulate matter ≤ 2.5 in aerodynamic diameter) is an important predictor of health levels [47–52]. Epidemiological evidence shows air pollution effects on neuropsychological development and impairment as well as on cognitive deficits and behavioral impairment in children and the elderly [50]. Some populations are at greater risk of mortality from the effects of poor environmental quality. For instance, older individuals with comorbidities such as myocardial infarction or diabetes are at greater risk of death associated with high exposure to $PM_{2.5}$ [47]. The risk of hospital admission and death from cardiovascular causes increase significantly with increased concentrations of $PM_{2.5}$ [48,49,51,52]. Moreover, increasing evidence suggests racial/ethnic minorities and low socioeconomic status populations experience greater exposure to $PM_{2.5}$, which may contribute to racial/ethnic and socioeconomic disparities in the adverse health outcomes associated with air pollution exposure [53–55].

1.4. SDoH Control Variables

The SDoH conceptual framework suggests that there are several other critical drivers of health over and above the three described earlier [5]. While these other factors are not the main focus of the research reported in this paper, they are nonetheless important to consider. Thus, income inequality, housing quality, food insecurity, educational attainment, and access to health care all have been shown to contribute to health outcomes [2,4,9,56].

In the US there are large and persistent racial disparities in health [57,58]. Discrimination and structural and cultural racism remain a fundamental cause shaping population health [58–60].

1.5. Expectations

Of the three variables of interest, energy burden is the least studied for its relationship with public health, particularly in the US context. In order to fully understand how energy burden connects to health, it is necessary to control for important competing explanations of health. This study moves beyond previous research by placing the effects of energy burden empirically within the context of the SDoH framework, by expanding the empirical setting to more than 2000 counties in the US (not only the larger cities subset most frequently studied), and by considering multiple measures of public health outcomes in US counties. Understanding the impact of energy burden on health outcomes is important. Given the complex nature of health, the critical question remains: does energy burden affect public health outcomes over and above the independent influence of social capital, environmental quality and other social determinants of health?

In order to focus this research, the present study of energy burdens, social capital, environmental quality and public health engages the following hypotheses:

Hypothesis 1 (H1). *Higher levels of energy burden within a county will be associated with poorer health outcomes, even when controlling for social capital, environmental quality, and a range of important social determinants of health.*

Hypothesis 2 (H2). *Higher levels of social capital within a county will be associated with better health outcomes, even when controlling for energy burden, environmental quality, and a range of established social determinants of health.*

Hypothesis 3 (H3). *Poorer environmental quality will be associated with poorer health outcomes within a county, even when controlling for energy burden, social capital, and a range of established social determinants of health.*

2. Materials and Methods

A range of existing county-level secondary data sources are employed here in order to better understand the complex structural determinants of public health. Multiple data sets are merged using County FIPS codes. The present research begins by collecting information on three different health outcomes across all US counties. The analysis relies on the County Health Rankings and Roadmap (CHRR) project for the measures of health and many of the variables noted in the SDoH framework. The CHRR data are augmented with other county-level secondary data sets reporting social capital and energy burden.

2.1. Data and Variables

Table 1 describes the variables used in this analysis. Health is a multifaceted concept not easily captured in a single empirical measure. Therefore, three different measures of health are employed in the models as separate dependent variables: premature mortality; self-reported health; and life expectancy. Premature mortality is a widely used indicator of population health. This is an age-adjusted variable where deaths that occur at younger ages are weighed more in the measure. Thus, premature mortality reports the number of deaths of county residents who are under 75 years. To compare across counties, this information is normalized by population and averaged across three years (2016–2018). In addition to premature mortality, the models used here also consider the percent of residents in a county who report fair or poor health. These data are found in the CHRR project and are drawn from the Center for Disease Control and Prevention's Behavioral Risk Factor Surveillance System. Self-reported health also is a widely employed indicator of health [61–63]. The final dependent variable is life expectancy, also reported in the CHRR project. This information is drawn from the National Center for Health Statistics and is an age-adjusted measure reporting the average life expectancy in a county. While this research presents a cross-sectional analysis, the variables representing health outcomes are based on data collected between 2016 and 2018 (as noted in Table 1). To strengthen the research design, the data representing the independent variables are based on information collected that predates the health outcomes examined in this research.

Table 1. Description of variables.

Variable	Description
Premature Mortality	This is the age-adjusted measure of premature mortality, the number of deaths among residents in a county who are under the age of 75 per 100,000 population. Reported in County Health Rankings and Roadmap (CHRR) using data from the National Center for Health Statistics from 2016–2018.
Self-Rated Health	The percentage of adults, age adjusted, within a county reporting fair or poor health. This is estimated using representative population health data (the Centers for Disease Control and Prevention's (CDC's) Behavioral Risk Factor Surveillance System) collected in 2017.
Life Expectancy	This is an age-adjusted measure that reports the average number of years a person can expect to live. Life expectancy accounts for the number of deaths in a given time period and the number of people at risk of dying during that time period. Reported in CHRR using data from the National Center for Health Statistics from 2016 to 2018.
Energy Burden	The county-level average proportion of income spent on housing energy bills for low- and moderate-income households. This measure is calculated using county-level Low-Income Energy Affordability Data available from the US Department of Energy. This was reported in 2016.
Social Capital	An index score compiled from publicly available sources and updated in 2014 [64]. This is based on a principal component analysis of four county-level variables: (1) the aggregate number of associations per capita including civic association, bowling centers, public golf courses, fitness centers, sports, religious, political, labor, business, and professional organizations per 10,000 people; (2) non-profit organizations without an international focus; (3) voter turnout, and (4) 2000 census response rate.
Environmental Quality	Average level of $PM_{2.5}$ in a county in 2014. Reported in the CHHR using data from the CDC's Environmental Public Health Tracking Network.
Income Inequality	Using 5-year estimates, this is the ratio of household income at the 80th percentile to the income at the 20th percentile. Reported in CHHR using data from the American Community survey from 2014 to 2018.
Inadequate Housing	The percentage of households within a county that are overcrowded or lack kitchen or plumbing facilities. Reported in CHHR using data from the American Community survey from 2014 to 2018.
Non-Hispanic Black	The percent of non-Hispanic Black or African American residents in a county in 2014. Compiled from Census data and available via the CHRR program.
Healthy Food Access	The percentage of low-income residents who do not live close to a grocery store in 2015. These data are compiled from USDA Food Atlas and available via the CHRR.
Access to Physicians	The ratio of primary care providers to the population in the county (per 100,000 people). These data are compiled by the American Medical Association and available via the CHRR.
Education	The percentage of adults in a county that are age 25–44 with some post-secondary education. Reported in CHHR using data from the American Community survey from 2014–2018.

Most of the independent variables employed here also are drawn from the CHRR project. However, measures of energy burden originate from the US Department of Energy (DOE). The Low-Income Energy Affordability Data (LEAD) Tool, created by the DOE, presents data, maps and graphs for understanding housing and energy characteristics for low- and moderate-income (LMI) households. From the LEAD Tool, the average county-level energy burden variable is calculated for electricity, natural gas, and other fuel expenditures. The energy burden variable is the percentage of income spent on housing energy bills for LMI households, where LMI is defined as households earning between 0 and 80% of the Area Median Income (AMI). Energy burden data from the LEAD Tool have been used to explore the spatial distribution of energy vulnerability across the

US and correlations with mortality rates and various demographic and socioeconomic characteristics at the county level [65].

The social capital measure used here is based on previously published and archived data [64]. This index score is produced by a principal component analysis of four county-level variables: including per capita civic associations, non-profit organizations, voter turnout and census participation. This measure has been widely used and is considered a valid measure of county social capital [66]. The analysis also includes a measure of environmental quality; relying upon the CHRR project, it includes a measure of air quality, specifically the average level of $PM_{2.5}$ in a county in 2014.

Using the SDoH framework as a guide, the analysis includes several control variables, all of which are extracted from the CHRR project. These measures include income inequality – a ratio of household income at the 80th percentile in the county compared to household income at the 20th percentile in the county [57]. Inadequate housing measures the percentage of households in a county that either experience over-crowding or inadequate plumbing. In the US, there are persistent racial disparities in health, therefore the analysis includes a measure of the percent of residents who identify as Non-Hispanic Black [58]. Access to healthy food and access to health care providers are also included as control variables and are found in the CHRR data set. The final control variable is educational attainment in the form of the percentage of adults with some post-secondary education.

These data are merged using County FIPS identifiers to construct a unique secondary data set that can examine the relative influence of energy burden, social capital, and environmental quality while controlling for other important determinants of health. Descriptive statistics are included in Appendix A.

2.2. Methods

This analysis explores how county-level factors shape health outcomes. In the US, counties are embedded within states and thus differences across states are likely to impact health. Therefore, this analysis uses a state fixed effect approach to model premature mortality, self-reported health and life expectancy. Preliminary diagnostics revealed spatial patterning in all three models making ordinary least squares (OLS) regression analysis inappropriate. Global Moran's I coefficient and its statistical significance were computed on model residuals to identify spatial autocorrelation [67]. For all three models, tests revealed a Moran's I, $p < 0.001$, indicating that model variables are in some way spatially clustered. Given such distributions, simple regression models would not account for spatially correlated errors and model results are likely to biased. Therefore, this analysis uses spatial error regression models to provide the most robust parameter estimates.

The choice of a spatial error models (SEM), as opposed to a spatial lag approach, is based both on statistical and theoretical grounds [68]. SEM assumes that the explanatory variables alone do not account for the spatial autocorrelation. This analysis relies on county level aggregate data and as such, we are not able to account for individual health behaviors that are part of the SDoH conceptual framework. These omitted parameters are likely to have spatially correlated factors, making a SEM suitable.

The SEM takes the following form:

$$y = \alpha \ + \ \sum_k \beta_k X_k \ + \ \lambda We + u \quad (1)$$

where y represents one of the three dependent variables (premature mortality, self-reported health or life expectancy), α is the constant, β is the coefficient for the k number of independent variables, λ is the spatial autoregressive coefficient, and W is the spatial weighting matrix, e is the random error term from OLS regression, and u is the spatially independent error term.

As the primary interest of this study is to understand how explanatory variables shape health outcomes, we rely on contiguity-based spatial weights. Contiguity-based spatial weights were estimated in Stata 16 using polygon map files from the US Census Bureau.

3. Results

Tables 2–4 present the results of the three analyses for factors shaping premature mortality, self-reported health, and life expectancy in US counties, respectively. The OLS model results are also presented for reference; the results of the independent variables are nearly the same. The SEM results are discussed hereafter. All three models highlight a consistent—and significant—relationship between energy burden and health. Communities that have more LMI households experiencing higher energy burdens also have poorer health outcomes. As energy burden increases so too do premature mortality rates within a county (Table 2). Across US counties, each unit of increase in LMI energy burden is associated with an average 240 more premature deaths per 100,000 people between 2016 and 2018. Similarly, as the energy burden increases across counties, each unit increase is associated with a seven percent increase in county residents that report experiencing fair or poor health (Table 3). Finally, each unit increase in energy burden is significantly associated with more than a five year decrease in county average life expectancy (Table 4).

Table 2. The results of spatial error models of factors shaping premature mortality in US counties.

Premature Mortality	OLS Model				Spatial Error Model			
	Coefficient	Std Error	95 % CI		Coefficient	Std Error	95 % CI	
Energy Burden	267.58	(25.42) ***	217.73	317.42	239.63	(26.45) ***	187.79	291.48
Social Capital	−3.28	(1.55) *	−6.31	−0.25	−2.10	(1.53)	−5.10	0.90
Environmental Quality	0.30	(1.43)	−2.50	3.11	−0.06	(1.65)	−3.30	3.17
Income Inequality	28.36	(2.36) ***	23.72	33.00	24.37	(2.27) ***	19.92	28.83
Inadequate Housing	99.70	(78.17)	−53.58	252.99	293.91	(77.68) ***	141.65	446.16
Non-Hispanic Black	71.31	(14.91) ***	42.08	100.54	102.38	(16.48) ***	70.08	134.67
Healthy Food Access	172.15	(22.34) ***	128.34	215.96	163.53	(21.54) ***	121.31	205.75
Access to Physicians	−15,557.55	(4773.23) **	−24,916.94	−6198.15	−16,171.95	(4485.64) ***	24,963.65	7380.25
Education	−277.47	(17.33) ***	−311.46	−243.48	−266.10	(16.86) ***	−299.15	−233.04
Constant	423.13	(23.07) ***	377.90	468.35	428.31	(25.85) ***	377.64	478.97
Lambda, λ					0.48	(0.03) ***	0.42	0.54
n	2871				2871			
R^2	0.60							
Adjusted R^2	0.59							
pseudo R^2					0.60			

Standard errors in parentheses; state fixed effects not shown. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3. The results of spatial error models of factors shaping self-reported health in US counties.

Self-Reported Health	OLS Model				Spatial Error Model			
	Coefficient	Std Error	95 % CI		Coefficient	Std Error	95 % CI	
Energy Burden	7.65	(0.66) ***	6.27	8.87	7.39	(0.68) ***	6.06	8.73
Social Capital	−0.42	(0.04) ***	−0.54	−0.38	−0.42	(0.04) ***	−0.50	−0.35
Environmental Quality	−0.11	(0.04) **	−0.20	−0.05	−0.05	(0.04)	−0.14	0.03
Income Inequality	1.15	(0.06) ***	1.08	1.32	0.99	(0.06) ***	0.88	1.11
Inadequate Housing	37.03	(2.00) ***	33.72	41.70	34.31	(1.94) ***	30.50	38.11
Non-Hispanic Black	8.57	(0.39) ***	7.74	9.27	9.79	(0.43) ***	8.94	10.64
Healthy Food Access	4.41	(0.52) ***	3.69	5.97	3.55	(0.49) ***	2.59	4.51
Access to Physicians	−117.50	(119.80)	−498.17	−2.05	−133.27	(109.09)	−347.09	80.55
Education	−11.00	(0.43) ***	−11.60	−9.83	−10.25	(0.41) ***	−11.05	−9.45
Constant	19.00	(0.60) ***	17.63	20.00	18.71	(0.69) ***	17.37	20.06
Lambda, λ					0.58	(0.03) ***	0.53	0.64
n	2925				2925			
R^2	0.84							
Adjusted R^2	0.83							
pseudo R^2					0.84			

Standard errors in parentheses; state fixed effects not shown. ** $p < 0.01$, *** $p < 0.001$.

Table 4. The results of spatial error models of factors shaping life expectancy in US counties.

Life Expectancy	OLS Model				Spatial Error Model			
	Coefficient	Std Error	95 % CI		Coefficient	Std Error	95 % CI	
Energy Burden	−6.32	(0.71) ***	−7.72	−4.92	−5.63	(0.75) ***	−7.09	−4.17
Social Capital	0.23	(0.04) ***	0.13	0.31	0.21	(0.04) ***	0.12	0.29
Environmental Quality	−0.16	(0.04) ***	−0.24	−0.08	−0.19	(0.05) ***	−0.29	−0.10
Income Inequality	−0.63	(0.07) ***	−0.76	−0.50	−0.56	(0.06) ***	−0.68	−0.43
Inadequate Housing	4.07	(2.20)	0–0.24	8.40	−0.63	(2.19)	−4.93	3.66
Non-Hispanic Black	−1.23	(0.42) **	−2.06	−0.41	−1.88	(0.46) ***	−2.79	−0.97
Healthy Food Access	−2.58	(0.66) ***	−3.86	−1.29	−2.45	(0.63) ***	−3.68	−1.21
Access to Physicians	133.52	(134.45)	−130.10	397.15	114.98	(126.61)	−133.17	363.14
Education	8.05	(0.49) ***	7.08	9.01	7.87	(0.48) ***	6.94	8.81
Constant	77.47	(0.65) ***	76.19	78.74	77.85	(0.73) ***	76.42	79.28
Lambda, λ					0.48	(0.03) ***	0.42	0.54
n	2859				2859			
R^2	0.54							
Adjusted R^2	0.54							
pseudo R^2					0.55			

Standard errors in parentheses; state fixed effects not shown. ** $p < 0.01$, *** $p < 0.001$

As noted earlier, prior research has established that social capital is an important determinant of health [25,28,29]. The results here are consistent with that past research. Social capital is statistically significant in the models of self-reported health and life expectancy. Higher levels of social capital are systematically related to lower percentages of residents reporting fair or poor health (Table 3). A county with a 10-point higher social capital score relative to another county experiences roughly 4 percent fewer residents reporting fair or poor health. Counties with higher levels of social capital also have significantly higher levels of life expectancy (Table 4). Each 10-point increase in social capital was associated with an increased average life expectancy of 2 years.

The measure of environmental quality (the annual average level of $PM_{2.5}$ in a county in 2014) is significant in only one of the three models, and the result is as expected. Changes in environmental quality are no more or less associated with rates of premature mortality or self-reported health across counties. Higher levels of $PM_{2.5}$ are associated with statistically significant lower rates of life expectancy (Table 4). Each 10-point increase in $PM_{2.5}$ across US counites is associated with a two year decrease in average life expectancy.

Overall, the remaining control variables suggest strong support for the SDoH framework. Income inequality—measured here as the ratio of household income at the 80th percentile to household income at the 20th percentile—is systematically related to poor health outcomes. This is in keeping with previous research findings; growing income inequality is significantly associated with all three measures of health [69–72]. Higher income inequality is linked to higher rates of premature mortality. Similarly, counties where the gap between the 80th and 20th percentile of household income is high also have systematically higher percentages of residents reporting fair or poor health. Finally, higher levels of income inequality within a county are linked to lower levels of life expectancy.

Inadequate housing (measured as the percentage of households that are overcrowded or lack plumbing or kitchen facilities) is significant in predicting increased premature mortality and self-reported poor health. In keeping with the large and growing literature that documents racial health disparities, the results indicate that race matters in shaping health. Counties that have a higher percentage of residents identifying as Non-Hispanic Black also have statistically higher rates of premature mortality, a higher percentage of residents reporting fair or poor health, and lower life expectancy. Similarly, access to healthy food is an important predictor of all three measures of health. Recall that this is the percentage of low-income residents who do not have access to a grocery store. As this percentage increases across counties, there are corresponding increases in rates of premature morality, increases in percentages of residents who report fair or poor health and declining rates of life expectancy.

The results also suggest that access to a physician matters, but not for all measures of health. In particular, this control variable is significant in only one of the models, namely premature mortality (Table 2). More per capita access to physicians is associated with lower rates of premature mortality in a county. The final control variable, education, is statistically significant across all three models and the results are consistent with prior research on the link between education and health. Counties that have more educated residents have lower rates of premature mortality, lower percentages of residents reporting fair or poor health, and higher life expectancy.

4. Discussion

Modeling three different measures of health provides an opportunity to compare more fully the relationships between health on the one hand, and energy burden, social capital, and environmental quality on the other hand. A challenge of this study was controlling for multiple determinants of health; nonetheless, strong patterns emerged across all three measures of health. Finding patterns of significance across models explaining different measures of health surely increases confidence in the results. Indeed, most of the variables had similar and expected relationships with health measures across the three models.

A limited number of studies have empirically explored the relationship between energy burden and health in the U.S while controlling for other variables known to have either positive or negative effects on public health. It was anticipated that higher energy burdens would be associated with poorer health outcomes. Across nearly all US counties, the analysis supports this expectation. Moreover, modeling results suggest this is an influential determinant of health across all three models, with only education and race having stronger influences on the health outcomes. Energy poverty is thus an important addition to the broader SDoH framework. High energy burdens for LMI households are particularly detrimental for population health. For instance, in the US, recipient families of the Low-Income Home Energy Assistance Program (LIHEAP) which provides financial assistance with energy bills, report often choosing between paying their energy bill or buying food, a situation commonly referred to as “heat or eat” which poses high health risks of malnutrition for children [73]. Recall also that the US Energy Information Administration also found that more that 25 million households reduce or forgo food or medicine in order to pay their energy bills [13]. If energy burdened households are unable to afford medical treatments, it is to be expected that the communities in which they live would experience increased levels of premature mortality, reduced life expectancy, and higher percentages of the population reporting they are in poorer health. Many state and local governments are beginning to consider the health implications of energy unaffordability and are launching programs that focus on improving energy efficiency and/or access to renewable energy in order to reduce energy consumption, improve housing quality, and reduce energy bills.

Social capital exhibits a significant positive effect on two of the three health measures, even when controlling for the effects of energy burden, environmental quality and other social determinants. Thus, to some degree it may be possible for the trust-based networks to compensate some for the negative health effects of energy burden. If greater energy burden produces an environment that either directly or indirectly is likely to lead to lower public health levels, the collective resource of social capital may produce some counterweight to energy burden’s negative health influence. The trust and reciprocity embedded in social capital’s foundation may be likely to spill over into some reservoir of support. However, it is important to note that social capital—while durable in some settings—is nonetheless dynamic and if depleted or low, is likely to take considerable time to develop. As social capital varies across counties, the resources associated with that capital also vary. A strategy to advance health by investing in social capital is a longer-term investment in community health and well-being.

Surprisingly, after accounting for spatial clustering, environmental quality was statistically associated with only one measure of public health, life expectancy. But measures of air pollution also can introduce complications. In this study, a single, annual average value of $PM_{2.5}$ at the county level is used; as a result, variability in air quality across a county is not well accounted for. Particulates may be directly emitted from a source such as engine exhaust fumes or formed in the atmosphere as a result of chemical reactions such as industrial activity. Therefore, PM2.5 tends to be higher in more urban areas with a higher level of traffic. Thus, the association between air pollution and health outcomes may need to be assessed at a smaller spatial scale than the county-level, such as zip code or census tract. However, other studies have found that higher $PM_{2.5}$ exposure was not associated with perceptions of higher concern about pollution-related health risks [74].

To be sure, this study is constrained by its character as an aggregate, observational analysis that does not directly observe the pathways through which energy burdens operate to shape health outcomes. However, other more limited previous observational studies suggest that theses pathways are present and provided the foundation for the hypotheses guiding this aggregate level study. The explicit analysis of pathways across large numbers of counties is an area for future study. It is also important to note that this study is confined to a single country, the US. While the nation-wide county-level database used here provides substantial variation in the size and cultures of the energy burden context, at the same time these findings may or may not be replicated in other national contexts. Results in other countries may vary based on different conjunctions of energy burden and health, as well as energy economies that are supported by different patterns of wealth, energy governance, or by energy sources that impinge on public health to a significantly different degree.

5. Conclusions

This study supports the social determinates of health framework and suggests that energy poverty should be included as a central component. To better understand how multiple, overlapping social determinants shape health, this study examined three different health outcomes across the majority of US counties: age-adjusted premature mortality, self-reported health, and life expectancy. In particular, this research examined the impact of energy burden, social capital, and environmental quality and their influence on all three health outcomes.

The research reported here clearly leads to the conclusion that the aggregate cost and availability of energy relative to the wealth capacity of individuals to pay for it has a significant effect on the health of those individuals. Those health effects of energy burden maintain across a range of health measures, from self-assessment to life expectancy to premature mortality. Moreover, those independent effects of energy burden emerge even when controlling for the well-established effects of social capital, environmental quality, and a broader set of social determinants of health. However, it also is clear that identifying the health effects of energy burdens does not erase the health effects of social capital and the social determinants of health more broadly. Thus, this energy burden analysis enhances both the understanding of the complexity of the causes of public health when aggregated at the county level and expands knowledge in a way that should provide new and innovative pathways through which public health can be enhanced, or at least can be protected. The implications of this paper contain a dynamic that may travel beyond the boundaries of health or energy burdens themselves. Additional concerns with energy justice may reside in a location external to energy burdens when those burdens themselves are disproportionately distributed among vulnerable populations, or when the negative health effects of those burdens are likewise inequitably distributed. If so, energy burden mitigation can provide a separate pathway toward the goal of public health equity.

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Appendix A

Table A1. Descriptive Statistics.

	Mean	Std Dev	Min	Max
Premature Mortality	407.05	111.18	127.77	1216.80
Self-Reported Health	17.94	4.65	8.12	40.99
Life Expectancy	77.43	2.92	61.63	104.74
Energy Burden	0.13	0.09	0.02	0.67
Social Capital	−0.05	1.17	−3.18	21.81
Environmental Quality	9.15	1.90	3.00	19.70
Income Inequality	4.52	0.74	2.54	11.97
Inadequate Housing	0.03	0.02	0.00	0.38
Non-Hispanic Black	0.09	0.14	0.00	0.85
Healthy Food Access	0.08	0.06	0.00	0.72
Access to Physicians	0.00	0.00	0.00	0.01
Education	0.58	0.11	0.20	0.90
n	2853			

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