# Energy bill security for American households through electrification

Sam Calisch, Rachael Grace, Gabe Daly, Ari Matusiak
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## 1 Summary


- There is a national conversation today about energy prices, whether for heating our homes or filling our gas tanks. Prices are going up, in some places resulting in over 50% increases in energy costs. The burden of these bill increases and uncertainty disproportionately impacts low- and moderate-income families. Because driving to work and keeping our homes warm are not discretionary expenses, bill increases represent real hardship for millions of American families.
- Much of the current conversation cites data from the U.S. Energy Information Administration's (EIA) *Winter Fuels Outlook*[1], which compares expected utility bill increases by heating fuel (i.e., propane, fuel oil, natural gas, electricity). These data are being misinterpreted in two key ways. First, the costs for electric heating have lumped together antiquated electric resistance systems with modern electric heat pump systems, obscuring the large savings made possible by these new technologies. Second, for homes heating with electricity, the data include all household electrical loads (e.g., lighting, televisions, etc.), whereas for homes heating with fossil fuels these are not included (despite the fact that these homes will also incur these costs).
- These two effects combine to meaningfully under-represent the advantages of efficient, electric heat pump technology. Indeed, households using natural gas for heat should expect to pay $161 more than last year over the heating season, and more than $500 greater for those using propane and fuel oil. Meanwhile, households with electric heat pumps can only expect to pay $21 more – just 13% of the cost increase gas heated homes will face.
- Heating costs are only part of the story of household bills; when we include driving, the other major component of household energy spending, the case for electrification grows even stronger. Compared to last year, average monthly driving costs are expected to be $118 higher for households driving gasoline vehicles, while only $4 higher for those with electric vehicles.
- Energy bill insecurity is driven by the inherent volatility of fossil fuel prices. Over the past two decades, home heating fuel prices fluctuated by ±50% and gasoline by ±60% from their means. Modern electric heat pumps would have supplied 38% lower bill volatility than fossil fuels for home heating. EVs would have cut driving bill volatility by 88%.[2]
- Even data from the past few days suggesting natural gas price increases may be less steep than anticipated[3] illustrates the highly volatile nature of fossil fuels. This volatility translates to increased uncertainty for American households.
- Policymakers should immediately address the current bill hardships American households are facing because of spiking fossil fuel prices. They also have an opportunity to get at the root cause of this repeating pattern by passing the electrification measures in the Build Back Better Act. Transitioning American households to efficient electric machines in their basements, garages and driveways will give American families the energy bill security they need and deserve.


[1] *Winter Fuels Outlook*, U.S. Energy Information Administration, October 2021.
[2] Here and subsequently we define volatility as the average absolute change in bills over the relevant time period.
[3] *Natural Gas Spot and Futures Prices (NYMEX)*, U.S. Energy Information Administration, December 8, 2021

## 2 Introduction

American households are likely going to pay a lot more for energy this winter. A number of factors, including the pandemic, extreme weather, and supply chain disruptions have combined[4] to push prices sky high for fossil fuels used for home heating and at the pump.[5]. This, combined with a colder than average forecast, will mean that homes using fossil fuels for heating will likely pay 30-55% more on their energy bills compared to last season.

These energy bill increases will create potential hardship for millions of American households, particularly the 15 million households below the federal poverty line, who already spend on average 17% of their income on energy bills[6], and have little financial capacity to deal with sudden price spikes. Because what we spend to drive our cars, heat our homes and water, cook our food and dry our clothes represent "inelastic demand" — what we must spend to keep our jobs and ensure our families are safe — energy bill security is paramount for all American households, and particularly for low- and moderate-income families.

In contrast to fossil fuel prices, electricity prices are only projected to rise modestly[7], especially in places that generate significant portions of their electricity from non-gas sources, like solar and wind. These forms of renewable energy are now the cheapest sources of new generation to install and operate[8][9]. They are also not subject to global supply disruptions, political instability and associated price shocks. For these two reasons, more renewable generation combined with efficient, electric homes will result in greater energy bill security, which all American families deserve.

We have the policy and technology solutions available today to provide relief both in the near and long term. Immediately, policymakers should help households through direct bill assistance programs like the Low-Income Home Energy Assistance Program (LIHEAP) and percentage-of-income payment programs (PIPPs). Beyond these crisis management measures, the long-term answer to combating future bill increases is residential electrification with clean, efficient machines. The good news is that, thanks to incredible advances in heat pump technology, electric vehicles and battery storage, all–electric homes are now a viable option for reducing energy bills in every climate in the U.S.

[4]See *What is behind soaring energy prices and what happens next?*. International Energy Agency, Carlos Fernández Alvarez and Gergely Molnar, October 2021.

[5]For example, by the end of 2021, residential natural gas prices are projected to increase 15-20%, hitting levels not seen since 2008. EIA Data browser.

[6]Low-Income Energy Affordability Data (LEAD) Tool, U.S. Department of Energy.

[7]The U.S. average residential retail electricity price is only projected to increase 3% by the end of 2021. EIA Data browser

[8]*Majority of New Renewables Undercut Cheapest Fossil Fuel on Cost*, International Renewable Energy Agenecy.

[9]*Wind, Solar Are Cheapest Power Source In Most Places*, BloombergNEF.

| Region | Natural Gas | Propane | Fuel Oil | Elect. Resist. | Elect. HP |
|---|---|---|---|---|---|
| New England | $76.49 (9%) | $600.76 (48%) | - (-) | $190.69 (13%) | $76.28 (13%) |
| Mid Atlantic | $128.24 (21%) | $600.76 (48%) | - (-) | $94.46 (8%) | $31.49 (8%) |
| E.N. Central | $257.27 (53%) | $677.12 (69%) | - (-) | $75.27 (7%) | $30.11 (7%) |
| W.N. Central | $208.99 (38%) | $677.12 (69%) | - (-) | $22.96 (2%) | $9.18 (2%) |
| South Atlantic | $100.10 (20%) | $455.40 (43%) | - (-) | $104.26 (10%) | $29.79 (10%) |
| E.S. Central | $233.51 (43%) | $455.40 (43%) | - (-) | $70.94 (6%) | $20.27 (6%) |
| W.S. Central | $62.59 (17%) | $455.40 (43%) | - (-) | $5.95 (1%) | $1.70 (1%) |
| Mountain | $124.35 (28%) | - (-) | - (-) | $9.44 (1%) | $3.15 (1%) |
| Pacific | $90.58 (18%) | - (-) | - (-) | $50.35 (5%) | $16.78 (5%) |
| U.S. Average | $161.09 (31%) | $582.16 (55%) | $524.00 (43%) | $64.11 (6%) | $21.37 (6%) |

Table 1: Projected heating bill increases from winter heating season 2020-2021 to 2021-2022, by region and by fuel type (natural gas, propane, fuel oil, electric resistance, or electric heat pump).

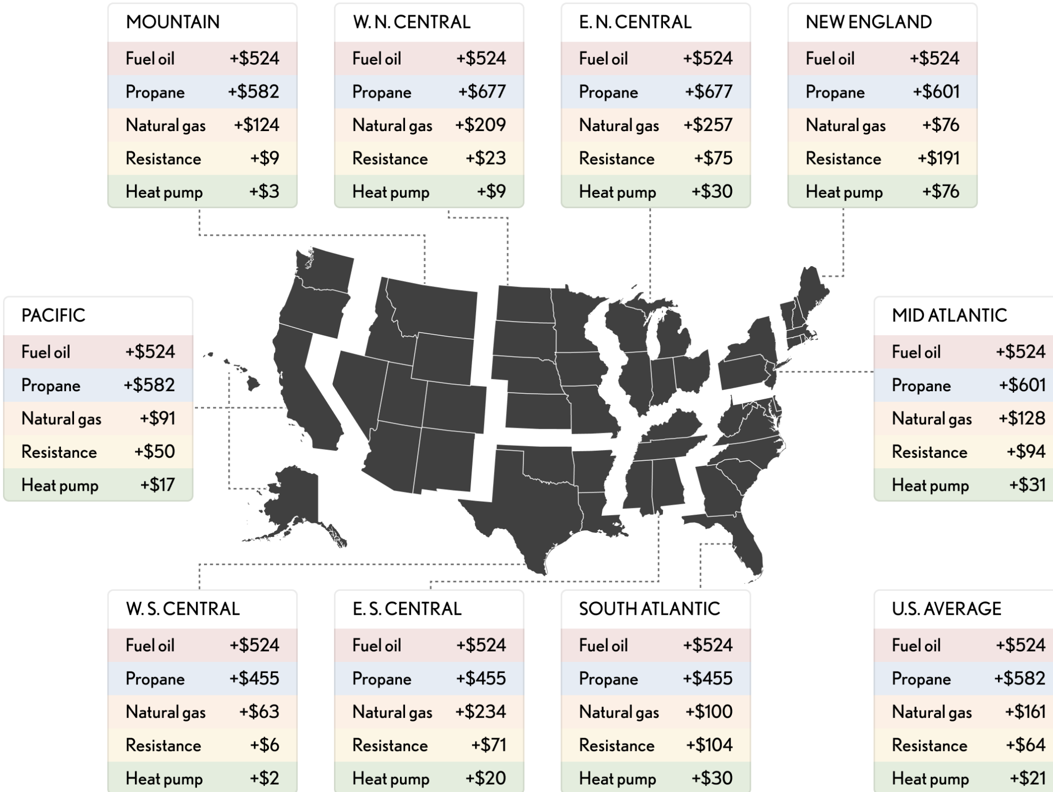


Figure 1: Regional breakdown of expected winter season heating bill increases from 2020 to 2021.

# 3 Projected household bills

In this section, we quantify the expected bill increases for the two largest categories of household energy expenditures: heating and driving.

## 3.1 Heating

When it comes to our energy use inside our homes, the major driver of bill increases is home space and water heating. In Table 1 and Figure 1, we tabulate the projected increases in seasonal[10] heating bills by region and fuel type. Here we use consumption and price data from the EIA's Winter Fuels Outlook. As noted previously, that study calculates total bills by fuel, which includes different end uses depending on fuel. For instance, a household's electricity bill contains a large number of non-heat end uses, which will be included in bills regardless of the main heating fuel. For this reason, we disaggregate expenditures by end-use to allow comparison between fuels. To do this, we use regional estimates of heat pump performance[11] and estimate regional share of electricity heating encompassed by heat pumps[12].

On average, households that heat with natural gas will likely pay $161 more this winter than last, while households using delivered fuels (propane and fuel oil) are likely to spend even more ($582 and $524, respectively). For households with electric heat pumps, energy bills are only expected to rise by only $21 more than last year. In every region of the country, the expected bill increase for natural gas households is greater than that of electric heat pump households. In some regions, like those in the Midwest, the natural gas bill increases are 8-20 times larger than that of electric heat pumps.

To see what this looks like on the ground, consider two neighboring households in rural Michigan.

[10] We follow the EIA's definition of the heating season as October through March, inclusive.
[11] *Bringing Infrastructure Home: A 50-State Report on U.S. Home Electrification*, Rewiring America, 2021.
[12] *American Housing Survey (AHS)*, U.S. Census Bureau, 2021.

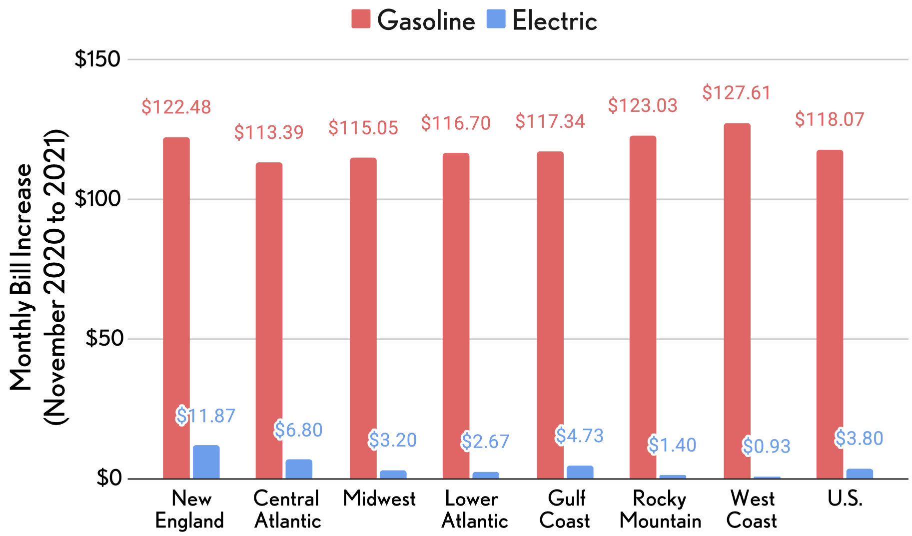


Figure 2: Household driving bill increases by region, from November 2020 to November 2021, comparing gasoline powered vehicles with electric vehicles.

In this setting, natural gas hookups are generally not available, and so delivered fuels (predominantly propane) are popular for home heating. Earlier this year, when their propane furnace needed replacement, the first household took advantage of an incentive for electric heat pumps offered by their utility. Now that winter has come, the first house expects to pay about $481 for heating over the course of the season, an increase of about $30 over last year due to slightly higher electricity prices and colder weather. The second household, however, who still burns propane, faces a bill of $1,660, an increase of $677 over last year. Even in nearby Detroit, where natural gas hookups are available, bill increases are expected to be dramatic. A household there should expect a bill of $745, an increase of $257 over last year.

Previous analysis by the authors[13] found that roughly 104 million out of the 121 million American households would save on energy bills by installing an electric heat pump for space or water heating. When this winter's energy bill projections are taken into account, that number grows to 115 million, or about 95% of all American households.

### 3.2 Driving

Besides home heating, the other place high fuel prices hit households is the price at the pump. This winter is projected to bring continued high gasoline prices, with the average expected household driving costs already exceeding $310 per month as of November 2021, an increase of $118 since the same time last year. In contrast, the average household electricity cost to power battery electric vehicles remains around $93 per month.

In Figure 2 and Table 2, we show increases to monthly household driving bills from November 2020 to November 2021, comparing gasoline- and electric-powered vehicles. We see on average, household driving bills with gasoline increased from $193 to $311, while for electric vehicle households, they only increased from $89 to $93. Returning to our Michigan households from before, we see a 64% increase in driving bills with gasoline, while only a 4% increase with electric.

[13] *Bringing Infrastructure Home: A 50-State Report on U.S. Home Electrification*, Rewiring America, 2021.

| Region | Gasoline 11/20 | Gasoline 11/21 | Increase | Electric 11/20 | Electric 11/21 | Increase |
|---|---|---|---|---|---|---|
| New England | $191.38 | $313.85 | $122.48 | $140.07 | $151.93 | $11.87 |
| Central Atlantic | $206.88 | $320.28 | $113.39 | $106.80 | $113.60 | $6.80 |
| Midwest | $179.54 | $294.59 | $115.05 | $84.73 | $87.93 | $3.20 |
| Lower Atlantic | $179.63 | $296.33 | $116.70 | $78.80 | $81.47 | $2.67 |
| Gulf Coast | $162.84 | $280.18 | $117.34 | $78.47 | $83.20 | $4.73 |
| Rocky Mountain | $201.28 | $324.31 | $123.03 | $76.67 | $78.07 | $1.40 |
| West Coast | $253.85 | $381.47 | $127.61 | $111.07 | $112.00 | $0.93 |
| U.S. | $193.39 | $311.47 | $118.07 | $89.00 | $92.80 | $3.80 |

Table 2: Projected monthly household driving bill increases from November 2020 to November 2021, by region and by fuel type (gasoline vs. electric).

# 4 Bill Volatility

This winter's bill projections may be stark, but they are not unprecedented. In this section we look at historical trends to examine bill volatility.

## 4.1 Heating

Figure 3 shows historical estimated winter season heating bills by fuel for the average American household at left. Indeed, variations in fuel prices and average temperatures give rise to significant variance in energy bills, especially for fossil fuels. As above, we distinguish between older electric resistance technology and newer, more efficient electric heat pump technology. To estimate historical heat pump operating costs, we use historical values of the average coefficient of performance[14].

In the right-hand graph below, we extract the twenty year average price volatility of these bills, defined as the expected year-over-year absolute change in bill. The greatest offenders are heating oil and propane, with a volatility of $200-300. Electric heat pumps are the hands down winner, with a volatility of $35, roughly 38% less than that of natural gas.

[14] The coefficient of performance is the ratio heat energy discharged into space or water versus the electric energy used to run the pump. We use an average value of 3.0 to represent today's heat pumps, and linearly interpolate back twenty years to a value just above 1.0.

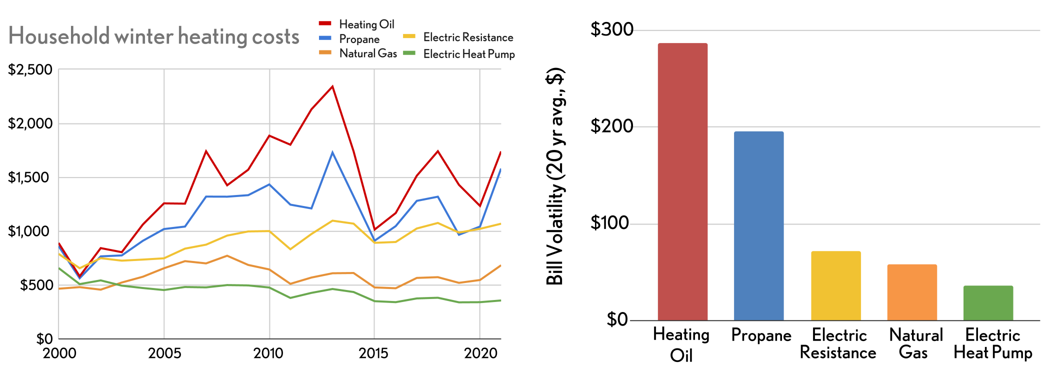


Figure 3: Average U.S. household heating cost variation by fuel type between 2000 and 2020. Electric heat pumps create stable winter heating bills compared to fossil alternatives.

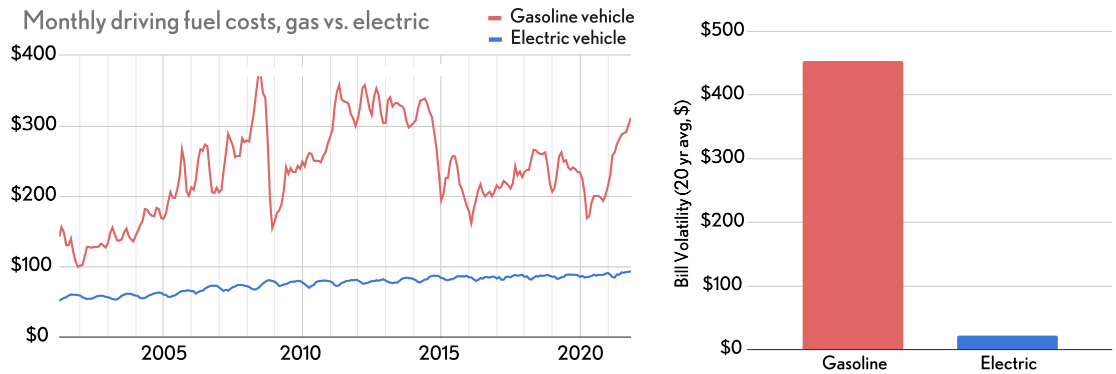


Figure 4: a) Historical comparison of fuel costs of gasoline powered vehicles and electric vehicles (had they been available on the mass market). b) Year–over–year driving bill volatility. Not only is the cost of driving an electric vehicle significantly lower than a gasoline powered vehicle, but it is also significantly less volatile.

### 4.2 Driving

In Figure 4, we compare the driving fuel costs for a household with gasoline vehicles versus one with electric vehicles. Clearly, fully electric vehicles were not available on the mass market during this historical period of analysis, but the comparison shows the trends we can expect now that they are.

We can see that a household driving gasoline vehicles should expect to pay around $250 per month, but that figure can easily vary by plus or minus $100. In contrast, a household with electric vehicles can expect to pay less than $100 per month, with a variability of only about $10. In annual bill volatility, the household bill volatility for gasoline vehicles is $454, while for electric vehicles it is $21.

## 5 What Policymakers Should Do

Policymakers must take immediate and decisive action to protect American households from rising energy bills, both this winter and for the years to come. Critically, there are steps at every level of government – local, state, and federal – that would help all households, particularly low- and moderate-income (LMI) ones, purchase and install efficient, electric machines.

### 5.1 Immediate Actions

Immediately, two policy solutions stand out as viable options for direct and targeted assistance: the federal Low-Income Heating Assistance Program (LIHEAP)[15] and the state-administered Percentage-of-Income Payment Programs (PIPPs). In addition, for existing efficiency and weatherization programs, efficient electric appliances should be the sole option for appliance installation, so that homes can benefit from the stability, comfort, and cost savings from heat pumps as soon as possible.

With respect to LIHEAP, multiple organizations have called on Congress to authorize an additional $5 billion in funding through the Build Back Better Act.[16]. As the National Association for Energy Assistance Directors' Association letter states, LIHEAP's funds will need to account for the increased prices this winter, amounting to a $2.5 billion decrease in its purchasing power.

PIPPs are currently utilized by a number of states to limit how much LMI households pay each year for their energy bills. The avoided costs for households are substantial, particularly because these programs can also include outstanding bill forgiveness. For instance, Virginia's PIPP, enacted into law

[15] Low Income Home Energy Assistance Program (LIHEAP), U.S. Department of Health and Human Services.
[16] *NEADA Calls for an Additional $5 Billion for LIHEAP for High Fuel Costs, Cooling Concerns*, National Energy Assistance Directors Association, October, 2021.

this year, can help Virginians with over $300 on their electrical bills per year, on average, and provides options to eliminate owed bills.[17] Before higher winter energy prices hit home energy bills, states should prioritize shoring up PIPPs so that funds are available when bills come due. And, in cases where programs can be established within this short time frame, such efforts should be prioritized. In all cases, streamlining these programs so eligible homeowners are automatically identified and, where appropriate, enrolled, would help ensure these necessary funds reach the homes that will need it the most. In support, Congress can pass emergency funding that flows to appropriate State agencies so that programs can provide these essential funds in the early part of 2022, just as winter utility moratoriums are coming to an end.

## 5.2 Sustainable Solutions

These immediate measures are important, but they do not solve the structural problem of energy bill volatility associated with fossil-fuel powered machines. Only electrification of our households will do that. The Build Back Better Act contains provisions that will serve as the down payment for this transition, and policymakers should understand its passage not only as a generational investment in addressing climate change, but also as a means of providing energy bill security to American households in every zip code in the country.

Specifically, the High-Efficiency Electric Home Rebates Act (formerly known as the Zero-Emission Homes Act) and the Home Energy Performance-Based, Whole-House Rebates and Training Grants (formerly known as the HOPE for HOMES Act) provide rebates for households to replace their space heating and cooling, water heating, cooking, and clothes drying appliances with efficient, electric versions. The High-Efficiency Electric Home Rebates are designed to be point-of-sale and will offer up to $14,000 for a LMI household to electrify their home. Critically, the High-Efficiency Electric Home Rebates also provide support for electrical work required to install such an appliance. These programs are also transferable to a third party, such as a contractor business, an installer, a retailer or a utility, making the process as seamless as possible for the consumer.

Between the Build Back Better Act and the Infrastructure Investment and Jobs Act (also known as the Bipartisan Infrastructure Deal), there are also new authorizations for subsidized low-cost loans and increased funding for weatherization and health and safety upgrades, crucial for many LMI homes to reduce energy bills but also to electrify. Upon enactment, States will have access to billions of dollars in new funding to support low-cost financing for heat pumps and induction stoves through newly established state green banks[18]. States will be able to weatherize more homes through additional funding to the Weatherization Assistance Program. And all building envelope efficiency programs can be done in conjunction with electrifying home appliances. These actions can be done in the near term so that next winter, or next summer, when heating and cooling needs are at their highest, Americans can avoid heat or cold stress, stay healthy, and save money while doing it.

In addition, states can direct appliance improvement funds under building envelope, efficiency, and weatherization programs to only fund efficient electric appliances and not gas, oil, or propane appliances. Practically, this would mean a state efficiency or weatherization program may install a heat pump water heater in a home in combination with insulation, air sealing, ventilation, and other health and safety improvements. Together, these efforts will meaningfully reduce energy use, costs, and indoor air pollutants for Americans in every region.

Indeed, these approaches are already taking hold. In Maine, for example, households are eligible for up to $1,200 in rebates for efficient heat pumps, as part of the state's effort to install an additional 100,000 heat pumps by 2025. To date, the program, run by the Efficiency Maine Trust, has already installed over 55,000 heat pumps and 33,000 heat pump water heaters. Combined with the other high efficiency and electric appliances the program has installed, the Efficiency Maine Trust expects up to $2 billion in cost savings for households [19].

[17] *2021 Special Session I: HB 2330 Percentage of Income Payment Program and Fund; DHCD & DSS to adopt rules, etc., for adoption,* Virginia Legislative Information System.

[18] See *Rewiring Communities: A Plan to Accelerate Climate Action and Environmental Justice By Investing in Household Electrification at the Local Level*, Adam Zurofsky, Jeffrey Schub, John Rhodes, Tony Curnes, and Sam Calisch, Rewiring America and Coalition for Green Capital, May 2021.

[19] *Efficiency Maine: FY2020 Annual Report*, Efficiency Maine Trust, November 2020

## 6 Conclusion

Projected high energy prices this winter, driven by fossil fuels and manifesting themselves in higher home heating bills and prices at the pump could create unnecessary hardship for millions of American families. Analyzing the data and the trend lines over the last twenty years shows clearly that the path to energy bill security for American households depends on electrification. Leveraging today's efficient, electric heat pump and electric vehicle technology is a triple win. It will deliver real savings to almost every American household, safeguard against future bill volatility and shock and materially contribute to addressing the climate crisis.

In order to make this transition in a timely way that all American households can benefit from, we must invest now in a series of rebates, tax credits, low-cost financing and other incentives to bring down the front-end cost of these efficient, electric machines. This will enable American households to take advantage of their operating cost savings – providing predictability – and spur the industrial scale necessary to achieve upfront cost parity with the incumbent, fossil fuel machines they will replace.

As we make these investments, it is important to note that the grid can accommodate the transition. Grid reliability is often raised as a counterargument to widespread electrification, especially with the 2021 Texas Blackouts fresh in the minds of homeowners. This is despite the fact such blackouts are infrequent[20], and, in the case of the Texas blackouts, natural gas infrastructure failures preceded and were the major cause of the electricity system shutdowns[21].

In reality, electrification has the potential to actually increase household energy reliability. Installing solar plus battery systems with "islanding" capability is increasingly becoming the norm[22]. During normal operation, such systems are tied to the grid, benefiting from net metering and grid services. During a power outage, these systems automatically disconnect from the grid, allowing the photovoltaics to continue generating power to be stored in the batteries and used locally, without any risk of pushing power back to the grid. Further, electric vehicle models like the forthcoming Ford F150 Lightning now ship with the hardware required for it to be used as a backup system, capable of powering a household for days[23]. Without also electrifying appliances inside the home, i.e., ensuring that the machines have plugs and not pipes, homes will simply not be able to take advantage of the powerful backup systems that will increasingly be in their garages and driveways.

Beyond the scope of a single household, electrification also stands to increase grid reliability. The added load of heat pumps and electric vehicles will certainly require increasing capacity of the transmission and distribution networks, but this is well within the scale of historical precedent. Fully electrifying all America's households will likely require about two to three times as much electricity to be delivered to the residential sector[24], and will take roughly twenty years to complete[25]. Critically, we have increased our capacity on that scale before: In the twenty years between 1950 and 1970, we increased the total amount of delivered electricity by nearly five times[26].

Further, concentrating investment in electric infrastructure will drive down the costs of these systems. Today, we maintain multiple redundant distribution networks for the fuels used in our households: power lines for electricity, pipes for natural gas, delivery trucks for propane and fuel oil. When we concentrate investment in the electrical distribution network, we can make these investments go further to boost reliability, particularly through undergrounding of wires[27]. When electrification is

[20] *Average frequency and duration of electric distribution outages vary by states*, U.S. Energy Information Administration, Annual Electric Power Industry Report (EIA-861).

[21] See *Winter storms wreak havoc on ERCOT grid,* Patrick Milligan, ICF, 2021. and *The Timeline and Events of the February 2021 Texas Electric Grid Blackouts*, University of Texas at Austin, July 2021.

[22] See *Storage is Increasingly Paired with All Forms of Solar*, Solar Industry Research Data, Solar Energy Industries Association. and *Behind-the-Meter Solar+Storage: Market data and trends*, Galen Barbose, Salma Elmallah, and Will Gorman, Lawrence Berkeley National Lab, July 2021.

[23] *Ford F150 Lightning will be a home backup power broker*, Green Car Reports, 2021.

[24] *The Rewiring America Handbook: A Guide to Winning the Climate Fight,* Saul Griffith, Sam Calisch and Laura Fraser, Rewiring America, July 2020.

[25] This length of time is set by assuming fossil machines are replaced with electric versions at the end of their useful life, rather than being retired early. With 10-20 year lifetimes common among these machines, and a few years required to ramp up production of electric machines, roughly twenty years are required to fully convert.

[26] *Table 7.2a Electricity Net Generation: Total*, Electric Power Monthly, U.S. Energy Information Administration.

[27] *Cost and reliability comparisons of underground and overhead power lines*, Utilities Policy, Steve Fenrick and Lullit Getachew, Volume 20, Issue 1, March 2012, Pages 31-37

paired with distributed generation and storage, demands on the distribution network can be greatly reduced and reliability increased [28][29]. Heat pumps and electric vehicles both offer massive opportunities for demand response[30], providing valuable grid services that increase reliability. And, in contrast to fossil fuels, a renewable energy-powered grid, bolstered by storage and paired with demand-side machines capable of demand response, can be insulated from the price volatility that adds stress and burden to American households.

Moments of price spikes and uncertainty require immediate action to prevent harm. But they can also point to the best and right path forward to ensure we solve the underlying issues and not consign ourselves to repeating the same experience. With respect to our winter heating bills and the price we pay at the pump, the answer to delivering energy bill security to American households is clear. It is time to invest in the electrification of our households, leveraging the opportunity of the Build Back Better Act to do just that.

## A Acknowledgements

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## B Methodology

In this brief, we have followed the methodology of the EIA's October 2021 *Winter Fuels Outlook*, as much as possible. To calculate consumption over the past twenty years, we use the EIA's estimates for the last eight seasons, fitting a linear regression based on the number of heating degree days. Then, using historical heating degree days from the EIA's Monthly Energy Review (Table 1.9: Heating Degree Days by Census Division).

Energy prices also come from the EIA: Weekly Heating Oil and Propane Prices: Residential heating oil, Weekly Heating Oil and Propane Prices: Residential propane, Natural Gas Prices, Form EIA-861M (formerly EIA-826) detailed data, Weekly Retail Gasoline and Diesel Prices. U.S. EIA.

Regional heat pump coefficients of performance were calculated using manufacturer–supplied performance curves (including those cataloged in the NEEP Cold Climate Air Source Heat Pump Specification and Product List). These performance curves were used in conjunction with local hourly dry bulb temperature data from NASA's MERRA2 dataset, and with NREL's hourly demand profiles for all TMY3 locations. Together these datasets are used in a model which calculates average coefficient of performance over the heating season (first used in Rewiring America's report, Bringing Infrastructure Home: A 50-State Report on U.S. Home Electrification), including contributions from hours in the year when backup electric resistance heating supplements heat pump capacity. To separate heating loads from total fuel consumption, the regional proportion attributable to space heating and water heating was extracted from NREL's hourly demand profiles for all TMY3 locations.

For the comparisons between gasoline and electric vehicles, the average vehicle miles traveled per household and gasoline fuel efficiency were estimated based on data from the Department of Transportation's Travel Monitoring Data and National Household Travel Survey. Electric vehicle efficiency was assumed to be the average of electric models listed on fueleconomy.gov.

[28] *Resilient Distribution Systems Powered by Solar Energy*, U.S. Department of Energy, Solar Energy Technologies Office.
[29] *Overview of energy storage systems in distribution networks: Placement, sizing, operation, and power quality*, Das et. al., Renewable and Sustainable Energy Reviews, Volume 91, August 2018, Pages 1205-1230
[30] *Beneficial Electrification: A Key to Better Grid Management*, Ken Colburn, Regulatory Assistance Project, 2017.