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From Emissions Inventories to Cost Accounting: Making Business as Usual Visible for Climate Action Planning

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Abstract: Greenhouse gas (GHG) inventories are widely considered a first step toward climate mitigation and adaptation planning, but progress completing inventories at the local level is often slow. Local governments may lack motivation to carry out inventories when staffing and funding are tight. Articulating the current costs of energy consumption could motivate cash-limited local governments and help justify investments in alternatives. Calculating financial savings of alternatives could further motivate planning. Here we demonstrate an approach to calculate operating costs (and potential savings) for a town in southern New York, using measures of heat consumption and eGallons to calculate expenditures. We find that business-as-usual community energy cost amount to \$50–\$60 million per year in funds exported from the community, or \$10,000–\$12,000 per household. By replacing gasoline vehicles with electric vehicles and oil-burning furnaces with heat pumps, the community could save around \$20–\$33 million per year, or \$4400–\$7000 per household. Local government operations costs could decline by over \$70,000 per year. For a small government, such reductions could have a substantial financial impact. Adding a cost assessment to a standard GHG inventory appears reasonably straightforward, and if implemented broadly, it could increase the speed and effectiveness of GHG inventories and climate action planning.

Keywords: climate action planning; cost accounting; electrification; greenhouse gas inventories; local planning

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1. Introduction

Greenhouse gas inventories provide a key first step toward planning for climate mitigation and adaptation in local communities and municipalities [1,2]. Progress is often slow in completing inventories, however. In New York State, for example, greenhouse gas (GHG) inventories, and subsequent climate action plans, have been promoted and financed since 2009 through the Climate Smart Community program [3]. Of the 1691 municipalities and counties in the state, only 86 had completed either GHG inventories or climate action plans by 2023. Most of these (77) had completed GHG inventories for local-government operations; half (44) had done inventories for community emissions. Only 27 had reported a climate action plan at either the municipal or community level. Much of this slow progress can be attributed to limitations of staff and funding resources in local governments [4]. Low motivation can also be a factor in the slow progress of inventories and climate action planning [1,4,5]. Local government officials face competing priorities, and immediate financial demands take priority over the more general goals of carbon reduction and global climate protection [4,5]. Mustering the effort to conduct inventories or plans often requires more immediate incentives.

In this context, one way to increase motivation may be to articulate the current costs of energy consumption. Accounting for, and making visible, "business as usual" (BAU) costs can help justify investments in alternatives. Another motivator may be to explore local financial benefits of alternative energy systems [5]. In this paper, we demonstrate an approach to both these financial assessments, building on data in hand from GHG inventories, for a town in southern New York.

Economic Framing

Leading justifications for undertaking GHG inventories have centered on the dangers of climate change and the health benefits of mitigation [2,6,7]. Both arguments can help justify the effort and cost of reducing emissions, but Marlon et al. [8] have shown that many Americans don't see the impacts of climate as an immediate or personal threat. Consequently, the general aim of emissions reduction can be a weak motivator for climate action [5,8,9]. Reframing the benefits of climate action as a financial matter can help convince local communities that they are directly impacted by climate action decisions [10].

Financial benefits of transitioning away from fossil fuels are becoming more evident, especially as more efficient and less expensive electric options become available [10] and [11] (p. 119). As analysts Bond and Butler-Sloss have argued, the narrative is shifting from the sacrifice of giving up fossil fuels to the financial (as well as environmental) gains and wealth generating capacity of electric alternatives [12].

Three particular economic cases can be important to local communities and local governing agencies: (1) financial savings of operation, (2) predictability of costs, and (3) keeping money in the community. In a study of electrification strategies for Washington, D.C., Pantano et al. (2021) observed that planned utility gas line maintenance was budgeted at $4.5 billion. They argued that this substantial funding could instead be used to cover $27,000 in upgrades to every household in the city using gas. This study concluded that "electrified housing is affordable housing", because electric energy and maintenance costs are lower, even compared to utility gas [13]. Similarly, Griffith and Calisch found that households can gain significant savings by switching from fossil fuels to electric alternatives [14]. Although electric alternatives can have a high up-front cost, low operating costs help give new equipment a rapid return on investment, especially if upgrades are implemented when aging equipment is due for replacement [15]. Fossil fuel costs can also be volatile, as they are affected by diverse global events from extreme weather to international conflicts [16]. Volatility in fuel prices is generally greater than that of electricity prices, which makes budgeting difficult [17]. For example, in winter 2023, US households faced as much as a 45 percent increase in fuel oil prices but only 11 percent in electricity prices [18]. Finally, Griffith [11] has argued that under current fossil-fuel systems, households and communities annually export large amounts of money in purchases of fuels, and he has asked what communities could do if, instead, they paid local producers to produce solar or wind power, thereby keeping funds in the local economy.

Electric options can have important efficiency advantages. EVs generally cost 50 to 70 percent less to operate, per mile driven, than gas-powered internal combustion engine vehicles. Maintenance costs are also lower, because EVs have fewer moving parts and fluids [19]. For space heating, electric heat pumps, which capture ambient heat and deliver it into (or out of) a building, are increasingly attractive alternatives to oil, propane, and natural gas [20]. Air-source heat pumps, which are less efficient but cheaper to install than ground-source heat pumps, still have efficiency rates of 300–500 percent efficiency (3–5 units of heat energy output for 1 unit of energy input). By comparison, oil furnace efficiency ranges from 85 to 90 percent efficiency, while new gas or propane furnaces achieve 95 to 99 percent efficiency.

Economic arguments are commonly offered as motivations for carbon reductions in other contexts. For example, carbon taxes and measures of the social cost of carbon are ways of putting a price on the extended impacts of carbon impacts [21–23]. The aim is to increase visibility of the larger social and environmental costs of business-as-usual carbon emissions. As alternatives become increasingly available, this cost accounting is also important for evaluating the direct financial costs of reliance on a steady flow of fossil fuels. Despite the rapid emergence of economic arguments in favor of electrifying fossil fuel energy uses, that conversation remains largely separate from community-level efforts to account for emissions and plan for climate action. In response to this gap, we show here a method for conveying these BAU costs for community energy use, as well as a method of calculating savings associated with electrification, using measures of heat consumption and electric mileage costs.

2. Materials and Methods

This study uses data from recently completed GHG inventories for a suburban town in New York State. The Town of Kent, NY has approximately 12,900 residents (4752 households) [24,25], many of whom commute to New York City or other regional cities for employment. We conducted two GHG inventories, one for municipal, or local government, operations (859 metric tons CO_2-equivalent, MTCO2e) and one for community emissions (148,000 MTCO2e). The inventories followed standard protocols [6,7] to calculate both energy consumption and GHG emissions from sectors including building operations, transportation, waste and wastewater management, and industrial process emissions [26,27].

Among energy consumption and emissions sectors, the largest were building heating (40 percent) and transportation (43 percent). The other sectors in the GHG inventory were waste and wastewater treatment (6 percent) and industrial process and fugitive emissions (5 percent). We focus here on the two largest sectors, heating and transportation (gasoline), because these represent major financial expenditures and because electric alternatives are readily available for both.

For BAU energy costs, we calculated the cost (in dollars) of fossil fuel consumption (in gallons of oil, propane, or gasoline), using energy consumption data from the municipal operations and community GHG inventories. Throughout this paper, we use conventional US units in order to retain consistency with all cited documents, data sources, and GHG inventories.

To assess alternative electric-powered energy costs, we calculated the cost to produce the same number of miles driven, or the same amount of energy consumed for heating, as in the BAU scenario (Table 1). We did this for gasoline and for heating fuels, both of which are readily converted to currently available (EV or heat pump) alternatives [28].

Table 1. Cost calculation terms used for energy sources, and conversions to electric units. For gasoline, fuel oil, and propane, consumption was converted to heat units (MMBtu) or kWh to allow comparison with electric options. Conventional US units are used in order to retain consistency with relevant documents, data, and inventories.

Source	Unit	Equivalents	Cost Calculation
Gasoline	gallon	eGallon equivalents	avg mi/gal × kWh/mi
Diesel fuel	gallon	none	$/gal
Fuel Oil	gallon	MMBtu equivalents	MMBtu/gal × $/MMBtu
Propane	gallon	MMBtu equivalents	MMBtu/gal × $/MMBtu
Wood	MMBtu	MMBtu equivalents	$/MMBtu
Electricity	MWh	none	$/MWh

We did not calculate alternative costs for some sectors, due to a lack of ready alternatives or of information. Electric alternatives are not readily available for diesel-powered heavy trucks. Baseline electricity consumption presumably includes low-efficiency equipment such as resistance heaters and older air conditioners, but we lacked information on the use of these appliances. Inventories also included waste, wastewater, and fugitive emissions, but these did not involve fossil fuel uses, so they were not addressed here.

The municipal operations inventory represented 2021, the most recent year for which complete data were available. The community report represented 2019, before the COVID-19 pandemic, which might have temporarily changed the community's patterns of travel and consumption.

Because we were interested in understanding the impacts of cost increases for both fuel and for electricity, we also calculated community costs using 2021 energy prices. We calculated both years only for the community costs, which were much larger (172 times larger) than the municipal costs.

2.1. BAU Transportation Costs: Fossil Fuels

To calculate the costs of gasoline in transportation, we used total miles driven per year, as reported in the GHG inventories. We divided miles driven by an average US miles/gallon, then multiplied the number of gallons by the 2019 (or 2021) regional average price per gallon.

Average passenger car fuel economy was taken from the DOE alternative fuels data center [29]. For gasoline-powered vehicles, the EPA reported an average fleet efficiency of 24.2 miles per gallon [30]. (This number is lower than in previous years, because of a growing number of sport utility vehicles and other larger vehicles in use compared to past decades.)

2.2. Alternative Transportation Costs: EVs

For mileage equivalents, we used the US Department of Energy (DOE) eGallon equation [31], which allows comparison of the price of one eGallon to the price of a gallon of gasoline. The DOE eGallon is calculated by multiplying the average US residential electricity price (EP) by the average comparable passenger car adjusted combined fuel economy (FE) by the average fuel consumption of the most popular electric vehicles in the US (EC), as (Equation (1)).

$$\text{eGallon (\$/gal)} = \text{FE} \times \text{EC} \times \text{EP} \tag{1}$$

where

FE = Average fuel economy for a car = 24.2 mi/gal [30]

EC = Average fuel economy of EV = 0.3 kWh/mi [31]

EP = Electricity price = 0.18 (2019) or 0.19 (2021) $/kWh or 0.16 (commercial 2021) [32]

The EV electricity consumption value was taken from the DOE Office of Renewable Energy and Energy Efficiency fuel economy database [33]. For 231 electric cars built between 2000 and 2022, reported efficiency varied substantially: The most efficient 54 vehicles in the EV database were rated at (0.24 kWh/mi), but for the best-selling EVs, mileage was approximately 0.3 kWh/mi [34]. Larger, less efficient vehicles were rated at over 0.38 kWh/mi. In our cost calculations we used a mid-range value of 0.3 kWh/mi.

We calculated eGallon prices for 2019 and 2021, using the average New York State residential electricity price for each year reported by the New York State Energy Research and Development Authority (NYSERDA) [32] (Table 2).

Table 2. Calculations for eGallon costs.

Inventory	Year	Cost/kWh	eGallon Cost Calculation
Municipal	2021	0.164	24.2 mi/gal × 0.3 kWh/mi × 0.164 $/kWh = $1.3863/gal
Community	2019	0.18	24.2 mi/gal × 0.3 kWh/mi × 0.18 $/kWh = $1.3150/gal
Community	2021	0.19	24.2 mi/gal × 0.3 kWh/mi × 0.19 $/kWh = $1.3863/gal

2.3. BAU Heating Costs: Fossil Fuels

Municipal building heating costs were calculated using billing records for gallons of fuel used, as reported in GHG inventories. We lacked data for municipal gasoline and diesel fuel prices, so we used community fuel costs ($/gallon) for heating oil and propane. The Town of Kent has no utility gas (natural gas), so it was not considered in calculations.

Community heating costs were also calculated from data in the GHG inventory, but for that report, heat consumption was reported in million Btu (MMBtu) for each different fuel. These MMBtu consumption rates were calculated from household "heating fuel preference" data reported by the American Community Survey (ACS) [25] and heat consumption rates reported by the US Energy Information Agency State Energy Data System (SEDS) [35]. To calculate fuel costs, we divided MMBtu consumption by the heat content of fuel (MMBtu/gallon), then multiplied gallons by the price ($/gallon) for 2019 or 2021 (Table 3). Residential heating sources in Kent were oil, propane, wood, and electricity. Heat content and prices of wood are highly variable, so we chose a representative price ($/MMBtu) from NYSERDA.

Table 3. Annual average costs used in calculations, from NYSERDA; energy conversion units to MMBtus.

Use	Fuel	Units	$/Unit (2019; 2021)	Conversion [36]
Transportation	Gasoline [37]	gal	2.64; 2.99	-
Transportation	Diesel [38]	gal	3.27; 3.43	-
Heating	Heating oil [39]	MMBtu	23.4; 33.5	1 gal = 138.5 MMBtu
Heating	Propane [40]	MMBtu	30.5; 33.5	1 gal = 91.45 MMBtu
Heating	Wood [41]	MMBtu	17.5; 18.3	-
Heating/other	Electricity (res) [32]	kWh	0.18; 0.19	1 kWh = 3.412 MMBtu
Heating/other	Electricity (com) [42]	kWh	0.14; 0.16	1 kWh = 3.412 MMBtu

Our BAU estimate is likely low, because our energy consumption data were available only as yearly totals, while fuel prices fluctuate continually. More heating fuel may be purchased in higher-cost winter months, but monthly price and consumption data were unavailable.

2.4. Alternative Heating Costs: Heat Pumps

Comparing heating demand among buildings or over time is difficult because heating, ventilation, and air conditioning needs vary with building characteristics, weather, and other factors. Lu and Zivani, for example, assessed energy costs and efficiency by instrumenting and monitoring a house for a year [43], an approach that provides important insights but is not readily replicated. As a more easily multiplied approach, we evaluated costs on the basis of heat consumption (MMBtus), which allowed an apples-to-apples comparison for different heating systems.

For municipal operations, we calculated MMBtus by converting reported gallons of fuel oil to MMBtu (at 0.1385 MMBtu/gal). To calculate heat pump costs from MMBtus consumed, we converted MMBtus to kWh: We multiplied the number of MMBtus by a standard measure of 298.08 kWh/MMBtu [44]; we then divided the number of kWh by a heat pump efficiency (coefficient of performance, or COP) value (Equation (2)). See notes on heat pump efficiency assumptions below. We then multiplied the number of kWh by a price per kWh. As with fuel sources, we used a regional annual average cost of electricity. For municipal electricity consumption, we assumed a 2021 commercial rate of 16.4 cents/kWh.

$$\frac{\text{n MMBTU}}{1} \times \frac{293.08\,\text{kWh}}{\text{MMBTU}} \times \frac{1}{\text{efficiency COP}} \times \frac{\text{n USD}}{\text{kWh}} = \$\,\text{total} \tag{2}$$

For community alternative electrical costs, which were reported in MMBtus for each fuel type (Table 3), we converted MMBtus to kWh, then multiplied by a $/kWh value (Equation (2)). For residential electricity, we assumed a residential price for energy, and for commercial electricity we used commercial rates. Commercial heating oil represented less than 1 percent of community consumption, so we used residential rates for all heating oil.

2.5. Heat Pump Efficiency Assumptions

In calculating electric heating costs, we assumed an efficient air-source heat pump. Ground-source geothermal heat pumps operate more efficiently than air-source heat pumps, but we assumed they would be less common in Kent because of higher installation costs and because local bedrock makes ground-source wells relatively difficult to install. This assumption may reduce estimates of financial savings reported here.

Heat pump efficiency can be calculated as the coefficient of performance, the ratio of energy output to energy input. For example, a modern heat pump might produce 3 joules of heat energy using one joule of electricity, for an output:input ratio of 3:1. Often this ratio is stated as 300 percent efficiency. Heat pump efficiency varies by machine model and with temperature. An air source heat pump works harder to compress refrigerants in cold weather, so efficiency (COP) is lower in colder temperatures. To approximate a standard COP for a high-efficiency unit, we plotted published values for three widely used Mitsubishi heat pumps across a range of temperatures [45–47]. We also plotted recent heating-season temperature normals (Figure 1) [48]. For average daily temperature ranges of around −6 to 4 °C (20–40 °F) in Kent, the three heat pumps report COPs ranging from below 2.5 to above 4 (Figure 1, gray shaded area). Taking a middle value, we assumed an air-source heat pump COP of 3.3 to represent a heating-season average performance of a newer heat pump [49].

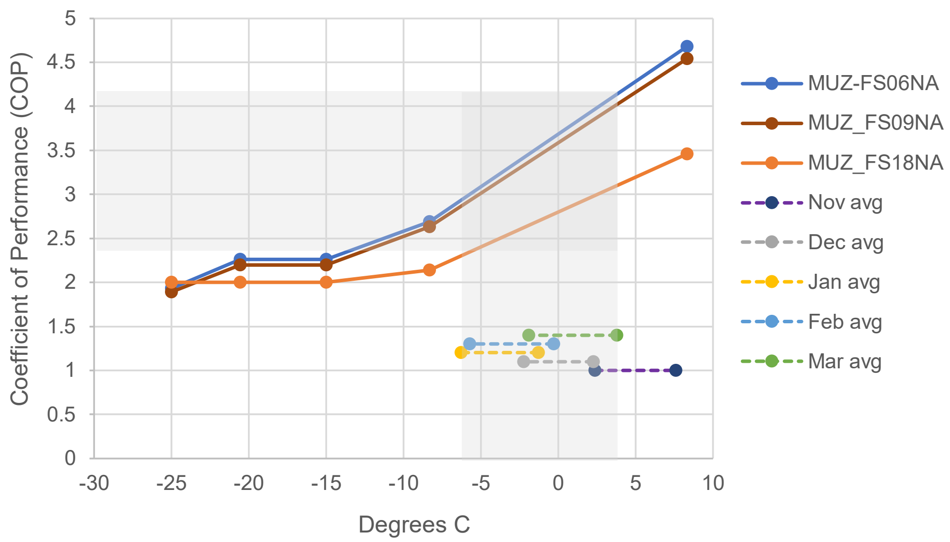

Figure 1. Published coefficient of performance (COP) values for three example Mitsubishi heat pumps, identified by model numbers [45–47]. COP values represent the ratio of energy output to energy input, and COP improves (rises) with moderate temperatures. Also shown are average daily low and high temperatures for heating-season months for Kent. Gray shading shows the intersection of average temperature ranges and COP ranges. (Figure created by authors.)

3. Results

3.1. Municipal Transportation and Heating Costs

BAU municipal vehicle gasoline usage for 2021 was 27,088 gallons, with a calculated cost of $80,993 (Table 4, row 1). Alternative (EV) equivalent costs for municipal gasoline for the same number of miles driven, came to $37,365. The cost savings for the municipality would be around $43,628 per year, using the 2021 commercial rate for electricity and an eGallon rate of $1.3863.

BAU heating with fuel oil in municipal facilities in 2021 was 1767 MMBtu, with a cost of $59,120 (Table 4, row 3). Producing that number of MMBtus with heat pumps would cost around $25,765. The difference in annual costs to the municipality would be around $33,355.

Table 4. Municipal costs and estimated percentage savings for fossil fuel use (FF) and electric alternatives (e−), 2021.

Sector	Source	Usage	Units	Cost FF	Cost e−	Difference
Vehicle Fleet	Gasoline	27,088	gal	$80,993	$37,365	$43,628
	Diesel	37,001	gal	$126,765	-	-
Buildings and Facilities	Fuel Oil	1767	MMBtu	$59,120	$25,765	$33,355
	Electricity	694	MWh	$113,932	-	-
Streetlights	Electricity	86	MWh	$14,118	-	-
Water and Sewage	Electricity	148	MWh	$24,297	-	-
Total				$419,225	$342,242	$76,983

Cumulatively, for local government operations, the town spent approximately $419,000 in 2021 (Figure 2). The largest portions of this cost were for electricity, diesel fuel, and gasoline. Our alternative electric equivalents reduced the cost by about $77,000 per year in operating expenses (Figure 2, Table 4).

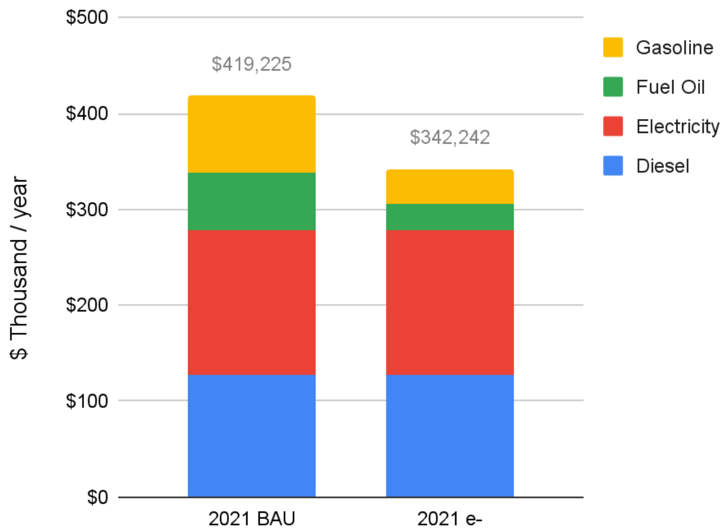

Figure 2. Town of Kent's municipal estimated annual operating costs, in thousands of dollars for BAU (**left bar**) and conversion to electric vehicles and heating (**right bar**). Colors are unchanged in the right two bars, to show relative expenditures for gasoline and fuel oil.

3.2. Community Transportation and Heating Costs

BAU community consumption of gasoline amounted to 6.8 million gallons, with a cost of $18 million (2019 prices) or $20 million (2021 prices: Table 5, row 1). The calculated cost rose in 2021 because gasoline prices rose by 13 percent between the two years (Table 5, right-most column). For comparison, the price of fuel oil rose 43 percent and propane rose 14 percent. Residential electricity rates (representing about 1 percent of consumption) increased 9 percent, but commercial electricity rates increased 17 percent.

Driving the same distance with an eGallon price would lower community transportation costs to $8.9 million in 2019 or $9.6 million in 2021 (Table 6, row 1). For EV costs, the difference between years was modest in part because residential electricity prices changed less than other major energy sources (Table 5, row 6).

Table 5. BAU Community consumption, prices, and total costs as calculated for 2019 (pre-pandemic) and 2021 (post-pandemic). All consumption data are for 2019, prices are for 2019 and 2021.

		Price ($/unit)		Cost ($1000)		
Fuel (Units)	**Consumption**	**2019**	**2021**	**2019**	**2021**	**% Change ***
Gasoline (gal)	6,842,062	$2.64	$2.99	$18,074	$20,458	13
Diesel (gal)	601,581	3.27	3.43	$1965	$2061	5
Heating oil (MMBtu)	582,674	23.4	33.46	$13,624	$19,494	43
Propane (MMBtu)	100,573	$30.49	34.62	$3067	$3482	14
FF sum: oil + propane				*$16,690*	*$22,976*	
Wood (MMBtu)	37,609	17.5	18.27	$658	$687	4
Electricity (res) (MWh)	61,551	$178.83	$194.25	$11,007	$11,956	9
Electricity (com) (MWh)	11,780	$139.92	164.17	$1648	$1934	17
Total				$50,043	$60,072	20
$/household ***				$10.5	$12.6	20

* Percentage price increase is calculated as (2021–2019)/2019. *** Cost/household calculated for 4752 households.

Table 6. Calculated costs and difference in total cost for fossil fuel use (FF) and electric alternatives (e−), in thousands of dollars, and percentage savings by fuel type. All consumption data are for 2019, prices are for 2019 and 2021.

	Cost FF ($1000)		**Cost e− ($1000)**		**Difference ***		**Cost Ratio ****	
Fuel	2019	2021	2019	2021	2019	2021	2019	2021
Gasoline (gal)	$18,074	$20,458	$8883	$9649	$9191	$10,809	0.49	0.47
Diesel	$1965	$2061	$1965	$2061	–	–	--	--
Fuel oil	$13,624	$19,494	$9226	$10,030	$4398	$9463	0.68	0.51
Propane	$3067	$3482	$1597	$1739	$1469	$1747	0.52	0.50
FF sum: oil + propane	*$16,690*	*$22,976*	*$10,824*	*$11,765*	*$5867*	*$11,211*	*0.65*	*0.51*
Wood	$658	$687	$597	$649	$60	$38	0.91	0.94
Electricity (res)	$11,007	$11,956	$11,007	$11,956	–	–	–	--
Electricity (com)	$1648	$1934	$1648	$1934	–	–	–	--
Total	$50,043	$60,072	$34,925	$38,015	$15,118	$22,058	0.70	0.63
$/household ***	$10.5	$12.6	$7.3	$8.0	$3.2	$4.6	0.70	0.63

* Difference 2019 to 2021 is calculated as baseline FF cost—alternative electric cost. ** Cost ratio is calculated as electric cost/fossil fuel cost. *** Cost/household calculated for 4752 households.

The difference between BAU gasoline expenditures and the alternative EV cost came to $9.2 million (for 2019) or $10.8 million (for 2021: Table 6, row 1).

BAU community heating costs for fossil fuels (oil and propane) amounted to $16.7 million in 2019 and rose to nearly $23 million with 2021 prices (Table 5, row 5). This change mainly resulted from the 43 percent increase in oil prices from 2019 to 2021 (Table 5, right column).

Producing the same number of MMBtus (as for oil + propane) with heat pumps would cost $10.8 million (2019) or $11.8 million (2021 prices). The cost of heating with electricity came to about half to two-thirds of the cost of heating with oil and propane (Table 6, right two columns).

By replacing fuel combustion furnaces with efficient electric heat pumps, and replacing gasoline-powered miles with EV miles, community costs could fall to around $42 million (Table 6, bottom row). This would reduce expenditures by around $15 million (in 2019) to $22 million (in 2021). Dividing this by 4752 households in Kent [50] produces savings of around $3200–$4600 per household on fuel consumption (Table 6, bottom row).

Cumulatively, the community spent approximately $50 million for energy in 2019, a cost that would decline by 30 percent under the alternative electrified model (Figure 3). This amounts to approximately $10,500 to $12,600 per household per year (Table 5, bottom row). Just over three-fourths of the BAU energy cost was spent on fossil fuels. The majority of spending was for gasoline (36 percent), fuel oil (27 percent), and electricity (25 percent) in 2019. With higher 2021 fuel costs, the difference increases to 37 percent under the alternative electrified model.

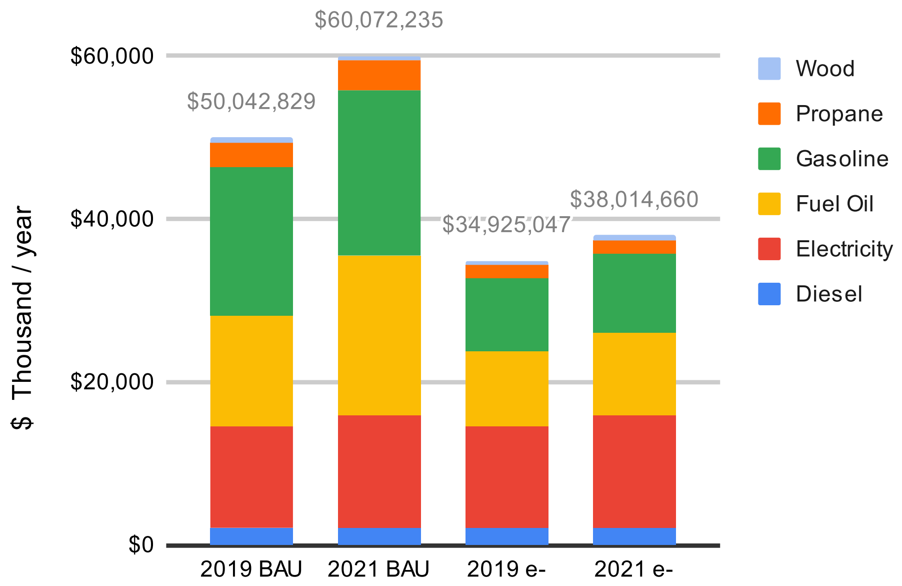

Figure 3. Calculated community BAU costs (**left two bars**) and electric costs (**right two bars**) using energy prices for 2019 and 2021. Colors are unchanged in the right two bars, to show relative expenditures of alternatives for gasoline, heating fuel oil, and propane.

4. Discussion

Growing evidence suggests that converting from fossil fuel combustion to electric systems lowers costs as well as emissions, but this economic argument is rarely present in standard GHG inventory practices [6,7]. Inventories provide an important opportunity to calculate costs, because they provide energy consumption data and because GHG inventories are considered a first step toward planning. Attention to current (BAU) costs can help make the value of an inventory clear when local officials need motivation. Calculating costs and benefits of alternatives can further motivate planning for both municipalities and households as they anticipate replacing aging equipment. The calculations demonstrated here, using the DOE's eGallon calculation and conversion of heating to MMBtus and to kWh, can help articulate the links between BAU fuel consumption and local financial considerations. This connection can help bring home the local importance of climate mitigation actions.

Our results suggest that savings can be substantial for communities that use fuel oil for heating or where commuting is important. Here, calculated efficiencies of EVs lowered vehicle costs by around half, and heat pumps reduced costs by 30–50 percent.

Of course, sources and prices of energy vary sharply among regions. Among US states, for example, prices of electricity varied from 10 cents to 33 cents per kWh (average 13 cents) in 2021, according to US Energy Information Agency data [51–53]. Average retail prices of oil varied from $2.70 to $3.40 per gallon (average $3.17). Utility gas varied even more, from $7 to $47 per thousand cubic feet (average $12). The relative prices of different energy sources, then, will influence estimated costs and savings in different areas. For many regions with utility gas lines, the calculated savings may be less than for regions relying on oil and propane, which are relatively expensive fuels. However, our study area also had high electricity prices: For example, the 2021 residential electricity price used here, 0.19/kWh, was higher than all but 7 other US states and was 43 percent higher than the national average price in 2021. For other states, then, the cost of operating a heat pump may be considerably lower. New York prices for oil and utility gas diverged less from US averages: Oil was just 6 percent higher than the national average and utility gas was

13 percent higher. Despite the high cost of electricity then, there were financial benefits in Kent for electrifying energy uses. Notably, Pantano et al. found comparable benefits for utility gas users in Washington, D.C. [13].

4.1. Making "Business as Usual" Visible

The point of a GHG inventory is to provide visibility for energy consumption and emissions. Making financial impacts legible is a reasonable next step. These cost estimates are necessary to provide context and comparison for any investment in new systems or infrastructure. They provide an important BAU starting point for climate action planning. They also show the amount of money that leaves the community each year, making it possible to consider where energy savings might allow funds to be redirected toward other priorities.

While these findings are a first approximation, they point to a few considerations for climate action planning. First, communities export a substantial amount of money on energy costs. The Town of Kent spends around \$50–\$60 million/year, or \$10,000–\$12,500 per household per year. While energy is a necessary cost, it amounts to a substantial drain on the community every year. Steps to reduce these costs could allow money to be redirected to other priorities in the community [11,12]. In Kent, local government operations alone spend over \$400,000 per year for energy. Many of these costs are difficult to reduce in the near term: heavy trucks and snowplows cannot yet be replaced with efficient alternatives. Other costs are easier to reduce: upgrading building heating and cooling or replacing some vehicles can save costs and have a relatively rapid return on investment.

Cost savings with electric equipment are likely to be substantial. If heating oil, propane, and gasoline usage were converted to electric alternatives, with no change in miles driven, heating practices, or building performance, the community could anticipate saving on the order of \$15–20 million per year in energy expenses. That amounts to roughly \$3000–\$4500 per household per year, for the years examined here. The municipality could anticipate saving around \$77,000 annually, based on 2021 records.

For reference, state grants to communities for planning and infrastructure upgrades are often in the range of \$5000 to \$10,000 [3], so an extra \$70,000 or so could do a good deal to support efficiency upgrades and other local government priorities.

4.2. Cumulative Savings Opportunities

This report presents current estimated yearly savings, but over multiple years, savings would multiply. These approximations assume no improvements in household efficiency measures, which could be paid for by accumulated savings in fuel costs. These savings would also be important in financing replacement costs of equipment and infrastructure.

Furthermore, while all energy costs rise over time, but electricity prices are generally less volatile than oil and gas, Low volatility improves budget predictability at both the municipal and household (community) levels. In our study area, electricity prices rose by 9 percent in the two years examined, while oil increased 43 percent, and gasoline and propane rose by 13 and 14 percent, respectively. In addition, the relatively high proportion of fossil-free electricity in New York may reduce volatility in the study area. Communities or municipalities that directly source local solar or other renewables may be able to further reduce cost variation and increases for electricity.

The US Department of Energy and the International Energy Agency expect costs of electricity to stabilize or even decline with more implementation of renewable energy and improved grid infrastructure [54,55]. The importance of improving and stabilizing supplies is reflected in recent federal policies that promote grid improvements and expansion [56,57].

4.3. Limitations and Further Work

This study provides an approach to calculating costs of fuel use, including the magnitude of BAU costs and the direction and amount of change with electrification. Further refinement of approaches like that shown here could improve the quality of, and confidence in, these estimates. In addition, calculating longer-term costs, including as cumulative maintenance and operating costs of BAU (and alternatives), would provide a more complete assessment. These calculations would require more detailed records, for example, maintenance and replacement history for municipal equipment, but they would allow for an assessment of return on investment for replacement equipment [13–15]. This level of information was beyond the scope of this study but would provide important insights for climate action planning.

Longer-term assessment would also benefit from inflation and financing costs, which would impact long-term cost estimates. This study also used average prices for all energy sources. Further studies also could augment the model by showing high and low estimates of energy costs, as well as calculating seasonal variation in fuel costs. Further studies in communities that use mainly natural gas would also be important. The Town of Kent relies on relatively expensive heating oil, but we have noted that at least one study of a city using utility gas, Washington, D.C., also projected substantial cost savings [13]. Further comparisons of communities with different energy mixes would be important to show ranges of cost impacts.

Although there are numerous ways to increase the level of detail in this study, our purpose was to demonstrate an approach to economic accounting that would be easy for other communities to replicate. More complex, long-term models, while more informative, would raise the threshold for communities that do not have abundant staffing or funding for assessment and planning [1,4,5], and thus a simple model like the one provided here may be more useful as a first approximation for many communities undertaking a GHG inventory.

5. Conclusions

This study shows an approach to calculating the costs of current fossil fuel energy consumption (BAU) in comparison to electric alternatives. It is novel in presenting an approach to representing GHG inventory data in financial terms. This representation can help make the value of emissions inventories evident to elected officials or community members who have not otherwise seen emissions reduction and climate action as priorities. Cost accounting is not generally a responsibility of GHG inventories, but an inventory provides a critical opportunity for accounting, as it provides the data needed to calculate costs and it precedes planning efforts. Thus, BAU cost accounting, and cost calculations for alternative options, could both motivate and inform climate action planning.

In the present case, municipal operations spent nearly $60,000 per year on building heating and nearly $81,000 on gasoline, both readily replaceable with alternatives that would cost less than half as much in annual operating costs. Community fossil fuel consumption cost $16.5 million to $23 million for heating fuels and $18 million to $20 million for gasoline. Electric alternatives could save around $3200 to $4600 per household per year. Those savings could help justify electric conversion at the household level.

In addition, we found that electric prices were less volatile than fossil fuels over the two years compared, with electricity prices rising 9 percent, compared to 14–43 percent for heating fuels. Better predictability in prices aids budget planning both for the municipality and for individual households.

Approaches such as this could facilitate climate action plans in communities that have historically lacked either funding, staff, or motivation to invest in planning for climate mitigation or adaptation. Including such calculations as a standard component of emissions inventories would help highlight the ongoing costs of business as usual. Cost assessment would also help justify upfront investments of transitioning away from fossil energy in fiscally conservative or financially constrained communities. This investment, at state, local, and household scales, is necessary for making progress from discussion to measurable progress in reducing emissions.

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References

1. Franco, C.; Melica, G.; Treville, A.; Baldi, M.G.; Ortega, A.; Bertoldi, P.; Thiel, C. Key predictors of greenhouse gas emissions for cities committing to mitigate and adapt to climate change. *Cities* **2023**, *137*, 104342. [CrossRef]
2. NYS Climate Smart Community Program. Pledge Element 2: Inventories Actions. Available online: https://climatesmart.ny.gov/actions-certification/actions/#open/action/6 (accessed on 1 June 2023).
3. NYS Climate Smart Community Program. Available online: https://climatesmart.ny.gov/ (accessed on 1 June 2023).
4. Allred, S.B.; Chatrchyan, A.M.; Tsintsadze, G. Local municipal capacity for climate change action in New York State: Exploring the urban–rural divide. *Rev. Policy Res.* **2022**, *39*, 570–601. [CrossRef]
5. Yazar, M. Norm domestication challenges for local climate actions: A lesson from Arizona, USA. *Environ. Pol. Gov.* **2022**, 1–12. [CrossRef]
6. ICLEI-Local Governments for Sustainability. Community Protocols. Available online: https://iclei.org (accessed on 1 June 2023).
7. Climate Smart Communities: New York Community and Regional GHG Inventory Guidance. 2015. Available online: https://climatesmart.ny.gov/fileadmin/csc/documents/GHG_Inventories/ghgguide.pdf (accessed on 1 June 2023).
8. Marlon, J.R.; Wang, X.; Bergquist, P.; Howe, P.D.; Leiserowitz, A.; Maibach, E.; Mildenberger, M.; Rosenthal, S. Change in US state-level public opinion about climate change: 2008–2020. *Environ. Res. Lett.* **2022**, *17*, 124046. [CrossRef]
9. Marlon, J.R.; Neyens, E.; Jefferson, M.; Howe, P.; Mildenberger, M.; Leiserowitz, A. Yale Climate Opinion Maps 2021. 2022. Available online: https://climatecommunication.yale.edu/visualizations-data/ycom-us/ (accessed on 1 June 2023).
10. Bond, K.; Butler-Sloss, S.; Lillis, G.; Sugihara, M. Peak Fossil Fuel Demand for Electricity: It's All Over Except the Shouting. Rocky Mountain Institute. 2023. Available online: https://rmi.org/insight/peak-fossil-fuel-demand-for-electricity/ (accessed on 1 June 2023).
11. Griffith, S. *Electrify: An Optimist's Playbook for Our Clean Energy Future*; MIT Press: Cambridge, MA, USA, 2021.
12. Bond, K.; Butler-Sloss, S. Gain Not Pain: Why COP Must Move the Narrative Forward. Carbon Tracker. 2021. Available online: https://carbontracker.org/gain-not-pain-why-cop-must-move-the-narrative-forward/ (accessed on 1 June 2023).
13. Pantano, S.; Calisch, S.; Munczek Edelman, D. Electrification Study for the District of Columbia. Rewiring America Report. 2021. Available online: https://content.rewiringamerica.org/reports/dc-electrification-report-final.pdf (accessed on 1 June 2023).
14. Griffith, S.; Calisch, S. No Place Like Home Fighting Climate Change (and Saving Money) by Electrifying America's Households. Rewiring America Report. 2020. Available online: https://content.rewiringamerica.org/reports/no-place-like-home-slides.pdf (accessed on 1 June 2023).
15. Higgins, T. Clean Energy Will Lower Household Energy Costs. Center for American Progress. 2021. Available online: https://www.americanprogress.org/article/clean-energy-will-lower-household-energy-costs/ (accessed on 1 June 2023).
16. International Energy Agency. World Energy Outlook 2021. Available online: https://www.iea.org/reports/world-energy-outlook-2021/prices-and-affordability (accessed on 1 June 2023).
17. Lee, M.; Billimoria, S. Eight Benefits of Building Electrification for Households, Communities, and Climate. Available online: https://rmi.org/eight-benefits-of-building-electrification-for-households-communities-and-climate/ (accessed on 1 June 2023).
18. EIA. Winter Fuels Outlook. October 2022. Available online: https://www.eia.gov/outlooks/steo/report/WinterFuels.php (accessed on 1 June 2023).
19. NYSERDA. Electric Vehicles. About Electric Cars—NYSERDA. Available online: https://www.nyserda.ny.gov/All-Programs/Drive-Clean-Rebate-For-Electric-Cars-Program/About-Electric-Cars (accessed on 1 June 2023).
20. Department of Energy. Heat Pump Systems. Available online: https://www.energy.gov/energysaver/heat-pump-systems (accessed on 12 July 2023).
21. Auffhammer, M.; Lin Lawell, C.-Y. C.; Bushnell, J.; Deschênes, O. Zhang, J. Chapter 4. Economic Considerations: Cost-Effective and Efficient Climate Policies. *Collabra* **2016**, *2*, 18. [CrossRef]
22. U.S. Environmental Protection Agency. The Social Cost of Carbon. 2015. Available online: http://www.epa.gov/climatechange/EPAactivities/economics/scc.html (accessed on 1 June 2023).

23. Wolak, Frank. Universities can do Better than Symbolism: A Revenue-Neutral Carbon Tax. *SIEPR Policy Brief. October 2014.* Available online: http://siepr.stanford.edu/publicationsprofile/2821 (accessed on 1 June 2023).
24. American Community Survey (ACS). Population Total. Available online: https://data.census.gov/table?q=Population+Total&g=060XX00US3607939331_040XX00US36 (accessed on 1 June 2023).
25. American Community Survey (ACS). Selected Housing Characteristics. Available online: https://data.census.gov/table?q=dp04&g=060XX00US3607939331_040XX00US36&tid=ACSDP5Y2020.DP04 (accessed on 1 June 2023).
26. Cunningham, M.A.; Leventhal, K.; Nahm, S.; Strope, N.; Rubbo, J.; (Vassar College, Poughkeepsie, NY, USA). Municipal Greenhouse Gas Assessment, Town of Kent, New York, 2019. 2023. Unpublished work.
27. Cunningham, M.A.; Leventhal, K.; Nahm, S.; Strope, N.; Rubbo, J.; (Vassar College, Poughkeepsie, NY USA). Community Greenhouse Gas Assessment, Town of Kent, New York, 2023. 2023. Unpublished work.
28. Holowka, T. Building Electrification: Why it Matters. USGBC. Available online: https://www.usgbc.org/articles/building-electrification-why-it-matters (accessed on 1 June 2023).
29. US Department of Energy, Alternative Fuels Data Center. Average Fuel Economy by Major Vehicle Category. Available online: https://afdc.energy.gov/data/10310 (accessed on 1 June 2023).
30. US Department of Energy, Office of Energy Efficiency and Renewable Energy. Available online: https://fueleconomy.gov (accessed on 1 June 2023).
31. US Department of Energy. The "eGallon". Available online: https://www.energy.gov/sites/default/files/2016/01/f28/eGallon%20methodology%20%28Updated%20January%202016%29.pdf (accessed on 1 June 2023).
32. NYSERDA. Monthly Average Retail Price for Electricity. Available online: https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/Electricity/Monthly-Avg-Electricity-Residential (accessed on 1 June 2023).
33. US DOE Office of Renewable Energy and Energy Efficiency. Available online: https://fueleconomy.gov/feg/evSelect.jsp (accessed on 1 June 2023).
34. Electric Vehicle Database. Available online: https://ev-database.org/cheatsheet/energy-consumption-electric-car (accessed on 1 June 2023).
35. US Energy Information Administration. State Energy Data Systems. 2023. Available online: https://www.eia.gov/state/seds/ (accessed on 1 June 2023).
36. US Energy Information Administration. Units and Calculators Explained. Available online: https://www.eia.gov/energyexplained/units-and-calculators/british-thermal-units.php (accessed on 1 June 2023).
37. NYSERDA. Motor Gasoline Prices. Available online: https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/Motor-Gasoline (accessed on 1 June 2023).
38. NYSERDA. On Highway Diesel Prices. Available online: https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/On-Highway-Diesel (accessed on 1 June 2023).
39. NYSERDA. Monthly Average Home Heating Oil Prices. Available online: https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/Home-Heating-Oil/Monthly-Average-Home-Heating-Oil-Prices (accessed on 1 June 2023).
40. NYSERDA. Monthly Average Propane Prices. Available online: https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/Propane/Monthly-Average-Propane-Prices#Middle-Hudson-Region (accessed on 1 June 2023).
41. NYSERDA. Wood Pellet Monthly Price Survey. Available online: https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/Wood-Pellet-Monthly-Price-Survey (accessed on 1 June 2023).
42. NYSERDA. Monthly Average Retail Price of Electricity—Commercial. Available online: https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Prices/Electricity/Monthly-Avg-Electricity-Commercial (accessed on 1 June 2023).
43. Lu, Z.; Ziviani, D. Operating cost comparison of state-of-the-art heat pumps in residential buildings across the United States. *Energy Build.* **2022**, *277*, 112553. [CrossRef]
44. American Physics Society. Energy Units. Available online: https://www.aps.org/policy/reports/popa-reports/energy/units.cfm (accessed on 1 June 2023).
45. Mitsubishi Electric Submittals. MSZ-FS06NA. Available online: https://drive.google.com/file/d/1ttw76eUdv9LYZ5CipVqfqk6ckgNbwH4V/view (accessed on 12 July 2023).
46. Mitsubishi Electric Submittals, MSZ-FS18-NA. Available online: https://drive.google.com/file/d/1pWgPaxyZQnQX0b6eqj_4lwE2No7Bq-jC/view (accessed on 12 July 2023).
47. Mitsubishi Electric Submittals, MSZ-FS09NA. Available online: https://drive.google.com/file/d/1fGVQlYuBS6CYqxKCvcvHd3-glDjeDoix/view (accessed on 12 July 2023).
48. Weather.us. Climate and Monthly Weather for Kent, NY. Available online: https://www.weather-us.com/en/new-york-usa/kent-climate#climate_text_12 (accessed on 1 June 2023).
49. IRENA. Renewable Solutions in End-Uses: Heat Pump Costs and Markets, International Renewable Energy Agency, Abu Dhabi. *ISBN: 978-92-9260-486-8.* Available online: https://www.irena.org/Publications/2022/Nov/Renewable-solutions-in-end-uses-Heat-pump-costs-and-markets (accessed on 1 June 2023).
50. US Census Bureau. QuickFacts, Kent Town, Putnam County, New York. Available online: https://www.census.gov/quickfacts/fact/table/kenttownputnamcountynewyork,NY/PST045221? (accessed on 1 June 2023).
51. US Energy Information Agency (EIA). Natural Gas Summary. Available online: https://www.eia.gov/dnav/ng/ng_sum_lsum_a_EPG0_PRS_DMcf_a.htm (accessed on 1 June 2023).

52. US Energy Information Agency. Weekly Heating Oil and Propane Prices. 2023. Available online: https://www.eia.gov/dnav/pet/pet_pri_wfr_dcus_nus_m.htm (accessed on 1 June 2023).
53. US Energy Information Agency. Electric Sales, Revenue, and Average Price. Available online: https://www.eia.gov/electricity/sales_revenue_price/ (accessed on 1 June 2023).
54. U.S. Department of Energy. Reimagining and Rebuilding America's Energy Grid. Available online: https://www.energy.gov/articles/reimagining-and-rebuilding-americas-energy-grid (accessed on 1 June 2023).
55. IEA. World Energy Outlook 2022. Available online: https://iea.blob.core.windows.net/assets/c282400e-00b0-4edf-9a8e-6f2ca6536ec8/WorldEnergyOutlook2022.pdf (accessed on 1 June 2023).
56. U.S. Department of Energy. Biden-Harris Administration Announces $13 Billion to Modernize and Expand America's Power Grid. Available online: https://www.energy.gov/articles/biden-harris-administration-announces-13-billion-modernize-and-expand-americas-power-grid (accessed on 1 June 2023).
57. Gearino, D. The Clean Energy Transition Enters Hyperdrive. Inside Climate News. Available online: https://insideclimatenews.org/news/25112021/clean-energy-transition-progress/ (accessed on 1 June 2023).