Estimating the Economic Impact of Potential Wholesale Price Increases in the Platte River Power Authority Service Area

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August 2019

EXECUTIVE SUMMARY

In December 2018, Platte River Power Authority (PRPA) announced a "resource diversification policy" to signify its intent to switch its electricity generation to a 100 percent "non-carbon energy mix" of sources by the year 2030. Because non-carbon energy production, transmission, storage and distribution is such a technologically dynamic area, there is uncertainty about the additional costs, if any, PRPA will incur to meet this goal. However, should PRPA's costs of providing reliable and efficient electricity to its four member utilities increase, it is likely that the electricity rates these member utilities charge will need to increase as well. Because electricity is an important expenditure for both businesses and households, rate increases can have important local economic impacts.

In this study, we estimate the economic impacts of a range of potential electricity price changes due to the proposed shift to 100 percent reliance on non-carbon energy sources for each of the four municipalities served by PRPA—The Town of Estes Park, and the Cities of Fort Collins, Longmont and Loveland. The price changes are imposed at the wholesale level. To gain a greater understanding of a wide range of price changes, we examine changes from a 20 percent decrease to a 100 percent increase. We examine impacts on both residential and commercial users.

To estimate the potential economic impacts of higher electricity rates, we construct a computable general equilibrium (CGE) model built specifically for the four municipalities served by PRPA. A CGE model is a tool that analysts use to describe the workings of a regional economy. Founded in both micro- and macro-economic theory, CGE models consider the economic interactions of households, businesses and government. Our CGE model considers 12 production sectors and 5 household income groups for each municipality. The model draws on a variety of national, state and local datasets on regional economic production and household demographics. We pay special attention to carefully modeling residential and commercial electricity demand, and the cost structure of both PRPA and the four municipal utilities. Although the full conversion to non-carbon generation is not targeted until 2030, the model examines how such price increases would impact the economy based on 2016 data. The structure of the economy changes slowly enough that this model could be used for approximately five more years.

The report provides detailed analysis for each of the four municipalities, considering the effects of potential rate increases on total output, employment and household income. Considering the impacts aggregated across the four communities, our model suggests that a 100 percent increase in wholesale electricity prices—an upper bound--would cause total service area employment to fall by 1,536 jobs (1.03 percent), real household income to fall by $85 million (0.83 percent) and domestic supply to decline by $291 million (1.3 percent). Looking at the lower bound of the range of price increases, the adverse impacts of a 10 percent price increase are much less severe. Here, total employment is expected to fall by 254 positions (0.17 percent), real household income is predicted to fall by $8.9 million (0.19 percent), and domestic supply is predicted to drop by $27.8 million (0.24 percent).

It is also important to note that any increase in electricity prices above wage inflation will adversely impact households, especially those with lower incomes. Our metric is the reduction in real household income (i.e., income adjusted for price changes). As expected, the lowest income earning households are impacted more negatively than higher earning households in all price increase scenarios. As an example, for Loveland in the 100 percent case the two lowest earning household groups lose about 1.3 percent. By comparison, Loveland's highest earning households experience about a 0.5 percent loss in real household income.

This study is not a benefit-cost analysis. Although the resource diversification policy change was motivated, in part, by a desire to reduce carbon emissions in electricity generation, we do not measure or estimate:

- any climate, environmental or health benefits from switching to 100 percent non-carbon sources
- any economic impacts due to the construction and installation of new generation infrastructure
- the impact of changing the structure of or decommissioning existing facilities

Further, we do not make any predictions about how this policy will impact future business location decisions, either through the stimulation of economic activity due to new opportunities or the change in the region's competitive position due to higher electricity prices.

INTRODUCTION

The Platte River Power Authority (PRPA) is a not-for-profit wholesale utility that provides electricity to four municipalities in northern Colorado: The Town of Estes Park, the City of Fort Collins, the City of Longmont, and the City of Loveland.[1] Each municipality subsequently resells this electricity to their residents and commercial and industrial consumers through their own municipally-owned and operated utilities.

In December 2018 PRPA announced a "resource diversification policy" to signify its intent to switch its electricity generation to a 100 percent "non-carbon energy mix" of sources by the year 2030, depending on the availability of key technological and market advancements. Because of uncertainty in both the pace and type of technological change in renewable energy generation, transmission and storage, as well as the continuing evolution of non-carbon electricity markets, there remains uncertainty about what additional costs, if any, PRPA will incur in order to meet this goal. However, should production costs increase, PRPA will likely pass on much of those costs to its member utilities, who, in turn, will likely pass on cost increases to their consumers through higher commercial and residential electricity rates.

In this study we describe the economic impacts of a menu of potential electricity price changes due to a shift to 100 percent reliance on non-carbon energy sources for each of the four municipalities served by PRPA. The price increases are imposed at the wholesale level and range from negative 20 percent to positive 100 percent. We examine impacts on both residential and commercial users. For residential users, we describe the effects of expected increases in annual electricity expenditures, and consider five "types" of households, which are delineated by income level. For commercial users, we model the impact on standard sectors such as retail, services, the health sector, etc. but we also identify three "types" of manufacturing groups distinguished by high, medium and low use of electricity. We are interested in how the level and distribution of output, employment and wage payments are affected by increased electricity prices for each type.

Although the resource diversification policy change was motivated, in part, by a desire to reduce carbon emissions in electricity generation, we do not measure or estimate any climate, environmental or health benefits from switching to 100 percent non-carbon sources. Nor do we estimate any economic impacts due to the construction and installation of new power generation, transmission and storage technologies that would be necessary to reach a total reliance on non-carbon energy. We also do not look at the impact of changing the structure of or decommissioning existing facilities to meet the total reliance on non-carbon energy. Finally, we do not make any predictions about how this policy will impact future business location decisions, either through the stimulation of economic activity due to new opportunities or the change in the region's competitive position due to higher electricity prices.

[1] PRPA's Board of Directors consists of the mayor and an appointed representative from each community.

MODELING APPROACH

To estimate the potential economic impacts of higher electricity rates, we construct a computable general equilibrium (CGE) model built specifically for the four municipalities served by PRPA. A CGE model is a tool that analysts use to describe the workings of a regional economy. Founded in both micro- and macro-economic theory, CGE models consider the economic interactions of households, businesses and government. CGE models are commonly used in economic impact analysis to analyze a variety of policy questions, including changes in electricity prices, income and sales tax rate changes, and the effects of a business entering or leaving a region. Appendices A and B provide additional information about the models we built for this study.

The focus of this analysis is to understand the impact of changes in electricity prices in the Platte River Service Area (PRSA). Generally, higher electricity prices impact the economy through several channels. The first channel is an adverse impact on household purchases of goods and services. Because nearly all households purchase electricity, an increase in its price means households typically have less income available to purchase other goods and services. This consequently lowers the demand for these items, reducing local economic activity. For example, if a household spends more on electricity, it will have less money to spend on going out to dinner. This negatively impacts restaurant spending. Here, in the language of economic impact analysis, the restaurant experiences an adverse *induced* impact. The magnitude of this impact will vary across household income groups because higher income households tend to spend more on electricity than do lower income households. However, because electricity is essential for operating nearly every housing unit, lower income households tend to spend a larger share of their budgets on utilities. An important aspect of our analysis is to describe the *distributional* impacts of higher electricity prices.

The second impact channel we consider is the effects of higher electricity prices on businesses. Because essentially all businesses in the PRSA purchase electricity (indirectly) from PRPA, electricity price increases will affect their cost structure, with at least some of the cost increase passed onto customers in the form of higher product prices. With higher prices, local businesses may become less competitive in local, national and global markets, and may see a decline in total sales. This is especially true for businesses that are relatively high users of electricity, such as a manufacturing facility or hospital. If output declines are significant enough, a business may have to reduce its workforce.

Overall, the magnitude of the impacts due to the price increase will depend largely on 1) the size of the price increase, and 2) the sensitivity of electricity demand by various user groups to price changes, including their ability to change behavior under higher prices.

Modeling Household Electricity Expenditures

The impacts of higher electricity prices on residential electricity demand and other household spending activity is a central aspect of our analysis. In CGE models, how much a household spends on electricity depends, in part, on the price of electricity, the relative price of any substitutes, and the household's income. With respect to the effects of price changes, we use our model to estimate how much a household with a given income would spend on electricity given different price levels. In conducting the analysis, it is critical to know: 1) how much different household "types" are currently spending on electricity, given its current price, and 2) how sensitive household electricity demand is to changes in its price (i.e., the price elasticity of demand).

Estimating annual household electricity expenditures in the PRSA

As noted above, electricity consumption is an important component of every household's budget. Economists tend to consider electricity a "normal" good, meaning that people consume more of it as their income increases. However, it can also be considered a "necessary" good, meaning households need to consume it regardless of their income level. Because of these features, electricity purchases represent a relatively larger share of low-income household expenditures and income than for similarly sized high income households. Accordingly, lower income households will likely be more adversely impacted by a price increase than higher income households.

As described in Appendix A, our model captures household income and expenditure heterogeneity by categorizing each household living in each municipality's service area in one of five income categories, denoted by "types" HH1 through HH5. Households categorized in HH1 are the lowest income households, with annual income of less than $15,000, while HH5 households are the highest earning households, and have income greater than $100,000.

After categorizing households by income, it is then necessary to model the spending patterns of each household type, especially their spending on electricity. Unfortunately, the communities in our analysis do not collect detailed residential electricity spending by household income group, instead offering only an average monthly expenditure for all residential users.[2] To remedy this, we use data from the US Bureau of Labor Statistics 2017 *Consumer Expenditure Survey* (CES), a survey-based data product that provides detailed information on household spending, including electricity expenditures, by income decile for the western US. This data allows us to compare how household spending on electricity in each decile compares to the "average" household's electricity expenditures. These relative ratios are then applied to the

[2] Average annual residential expenditures were derived from select 2017 public reports for the four utilities and municipalities. Due to limitations in data availability for the specific service boundaries of the various city municipalities, our data set does not exactly replicate the number of residential consumers served by any particular utility. Thus, total household expenditures in our analysis differ slightly from the total residential revenues reported by the utilities. However, because we are most interested in how individual households are impacted, rather than the total impacts on utility revenue, we believe our approach is more informative. Because our total household numbers are quite close to the reported number of residential customers, a more accurate matching of utility revenue and household electricity expenditures would change our results only marginally.

average monthly household electricity expenditure reported for each of the municipalities in the PRSA and mapped into our model "types" to get a predicted spending per household for each household income group in our model. Table 1 shows our estimated annual electricity spending for each household type in each of the four communities of interest. The first data column presents the total annual payments by each household group in the four municipalities. The second column presents the percent of the household's expenditures that are allocated to electricity and the last column is the average monthly household electricity expenditure.

Table 1. The Distribution of Household Payments for Electricity, by PRSA municipality[3]

Household Income Group	Total Payments for Electricity (mil of $)	Electricity Payments as a Percentage of Household Expenditure[4]	Average Monthly Payment per Household
Longmont (average residential monthly bill: $65.19)			
HH1 ≤ $15,000	1.68	1.71%	$43.45
$15,000 < HH2 ≤ $25,000	1.86	1.51%	50.47
$25,000 < HH3 ≤ $75,000	10.74	1.30%	63.65
$75,000 < HH4 ≤ $100,000	3.82	0.94%	71.23
$100,000 < HH5	9.96	0.49%	85.36
Loveland (average residential monthly bill: $66.11)			
HH1 ≤ $15,000	1.23	1.01%	$43.01
$15,000 < HH2 ≤ $25,000	1.85	1.55%	50.03
$25,000 < HH3 ≤ $75,000	10.36	1.21%	63.07
$75,000 < HH4 ≤ $100,000	3.93	0.97%	70.51
$100,000 < HH5	6.85	0.36%	84.53
Estes Park (average residential monthly bill: $82.66)			
HH1 ≤ $15,000	0.18	0.48%	$54.08
$15,000 < HH2 ≤ $25,000	0.88	2.37%	62.81
$25,000 < HH3 ≤ $75,000	2.46	0.96%	79.21
$75,000 < HH4 ≤ $100,000	1.02	0.85%	88.66
$100,000 < HH5	1.54	0.30%	106.23
Fort Collins (average residential monthly bill: $65.19)			
HH1 ≤ $15,000	3.72	1.35%	$43.95
$15,000 < HH2 ≤ $25,000	3.74	1.38%	51.05
$25,000 < HH3 ≤ $75,000	17.76	0.96%	64.27
$75,000 < HH4 ≤ $100,000	7.00	0.73%	71.98
$100,000 < HH5	15.76	0.38%	86.28

The important takeaways from Table 1 are as follows. Longmont, Loveland and Fort Collins have similar characteristics with respect to annual household electricity payments; Estes Park

[3] Average monthly residential expenditures are quite similar in Loveland, Longmont and Fort Collins. They are higher in Estes Park. This is likely due to economies of scale, differences in population density, and differences in the reliance of electricity versus gas in home heating.

[4] This column is based on CES data and reports electricity expenditures as a share of total household expenditures.

averages are higher. Generally, HH1 and HH2 have the largest percentage of budget allocated to electricity payment compared to the other three household groups. This indicates that when we increase electricity prices, the lower income earning households will be more negatively impacted.

Modeling the own-price elasticity of residential electricity demand

Numerous economic studies have estimated the own-price elasticity of electricity demand for residential customers. A recent study[5] of water and electricity demand in Fort Collins concludes that it is -0.16. This means that a 1 percent increase in the price of electricity will lead to a 0.16 percent decline in the quantity of electricity demanded. We use this value in the household demand function in on our CGE model.

Modeling Commercial and Industrial Electricity Expenditures

As noted above, electricity is needed to operate nearly every business, and, for some operations, electricity purchases can represent a relatively large share of their overall expenses (e.g., some manufacturing facilities, big box retailers and hospitals). Accordingly, an increase in electricity prices can directly and adversely impact businesses through higher production costs. Typically, economists expect that as per unit production costs increase, businesses will produce less output and need to charge a higher price for their product. This has four impacts in the economy that we capture in our model. First, when a business reduces its output, it tends to need fewer workers. Thus, the demand curve for labor shifts inward, reducing both total employment and wages in the economy. Second, output reductions lower the demand for not only workers but other factors of production as well. If these factors are produced locally, the local supplying businesses will feel the effects. Economists refer to this as the *indirect* effect. The third impact is that a reduction in employment reduces total household wage income, and subsequently lowers the demand for goods and services in the economy. (This is the akin to the induced impact referred to above). Finally, with higher prices in the economy, household's purchasing power falls, and meaning they buy fewer goods and services.

To capture these effects in a CGE model we need to accurately model commercial and industrial electricity expenditures. While each municipal utility provides information on total electricity expenditures by such customers, they tend not collect information on the specific industries in which these businesses operate. Such information is essential, however, as some sectors are relatively more intensive users of electricity than are others. Accordingly, some industries may be more impacted than others by a price increase.

In this study we derive industry-level electricity expenditures from the IMPLAN database, a county-level economic modeling system that provides detailed estimates of industry input purchases for more than 500 sectors. In our CGE model, we aggregate the production side of the economy into 12 industries, based on NAICS classifications. Because manufacturers have a great variability in the importance of electricity as an input, we disaggregate this sector into: 1

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[5] Maas, A., C. Goemans, D.T. Manning, J. Burkhardt and M. Arabi. (2019). "Complements of the House: Estimating Demand-side Linkages between Residential Water and Electricity." Water Resources & Economics (in press).

high-users, 2) medium-users and 3) low-users, with the differentiation driven by the share of total input purchases dedicated to electricity. Our total industry-specific expenditures are then reconciled with the total revenues from commercial and industrial customers reported by each utility.

Modeling the own-price elasticity of commercial and industrial electricity demand

Several previous studies have estimated the own-price elasticity of electricity demand for commercial customers. The consensus is -0.22 in the short-run. This means that a 1 percent increase in the price of electricity will lead to a 0.22 percent decline in the quantity of electricity demanded in the short-run. We use this value in the industry electricity input demand functions in on our CGE model.

RESULTS

At the time of this report, PRPA is uncertain about how much generation and transmission costs will increase when they fully convert to 100 percent non-carbon energy. To account for this uncertainty, we use the model to examine wholesale electricity price increases ranging from 10 percent to 100 percent. (We also estimated the results with falling electricity prices, with rates declining by 10 percent and 20 percent, perhaps due to significant technological changes). It is important to note that the electric utility sector of the model is constructed based, in part, on the most recent financial reports provided by the individual utilities and municipalities with respect to their operating expenses. We assume that electricity purchases are the only utility expense that changes with the wholesale price increase. The upshot is that, because wholesale electricity purchases account for between 52 percent and 68 percent of total utility revenues for the four municipal electric providers, consumer, industrial and commercial rates are predicted to increase by less than wholesale price percentage increases.

The tables below present results from simulations of electricity price increases of 10 percent, 20 percent, 40 percent, 60 percent, 80 percent and 100 percent. In Appendix D a 10 percent and 20 percent fall in electricity payments are modeled. Although the full conversion to non-carbon generation is not targeted until 2030, the model examines how such a price increase would impact the economy as it stood in 2016.[6] Most of our discussion will revolve around the 10 percent and 100 percent cases but the reader is encouraged to also consider the cases in between the lower and upper bounds.

[6] The CGE model is a static model. This means simulation results can be thought of as a "before and after" analysis. In the case of this analysis, we can think of the impacts being the effects of an instantaneous price change (for example, an overnight doubling of electricity prices in the '100 percent' increase scenario). However, conversations with PRPA indicate that any price changes are likely to be applied over several years. Because the economy is constantly evolving, it is expected that the region's economic structure will change during the period price changes are implemented. Thus, the ultimate price change may apply to a "different" economy than the one that exists today. Our model's results could be impacted in such an environment, but we think the differences would be small given the relatively stable evolution of the Front Range economies. Further, it is also true that the regional economy should see some inflation over time. For simplicity, we assume that inflationary pressures are the same across all sectors of the economy, thus negating the need to incorporate it in our analysis.

We present the results from several different perspectives. First, we examine the aggregate level of economic activity by combining all four municipal service areas. Total employment describes the state of the labor market, while real household income indicates the standard of living of households in the economy. The third factor we present is domestic supply, or the level of production by all commercial and industrial businesses in the economy. We next decompose these three indicators into values at the individual utility service area level. This provides a perspective on the degree of unevenness that an increase in electricity prices may have across the four municipalities. The final discussion examines how different household groups, distinguished by annual income, are impacted by higher electricity prices in each utility service area.

In 2016, Platte River generated $179.2 million in revenue (PRPA sales) from municipal utilities in Longmont, Estes Park, Loveland and Fort Collins (Table 2). This electricity was subsequently re-sold to commercial and residential consumers for $280.6 million. For example, Longmont Power & Communications spent $47.1 million on electricity purchases from PRPA, which it then sold to its household and commercial users for $28.1 million and $49.6 million, respectively. The difference between the value of final electricity sales and the wholesale purchases from Platte River is the amount of money needed to operate the municipal electricity utility (e.g., administration, local distribution, maintenance, etc.).[7]

Table 2: Electricity Expenditures from Platte River and the Four Municipalities

Municipality	PRPA Sales (wholesale) (millions of $)	Final Household Expenditures (millions of $)	Final Commercial Expenditures (millions of $)	Total Municipal Revenue (millions of $)	PRPA Sales as Share of Total Municipal Revenue
Longmont	47.1	28.1	49.6	77.6	60.7%
Estes Park	7.2	6.1	7.6	13.7	52.6%
Loveland	41.6	24.2	36.3	60.6	68.6%
Fort Collins	83.3	48.0	80.8	128.7	64.7%
Total	179.2	106.4	174.3	280.6	63.9%

Source: Municipal utility reports and PRPA

Dividing the total of the first data column of Table 2 by the total of the fourth data column shows that wholesale electricity purchases comprise about 63.9 percent of total municipal utility revenues. Applying this percentage to the household and commercial expenditure columns gives an estimate of total wholesale electricity expenditures by final customer type. Here, we approximate that $67.95 million of total household electricity expenditures are (eventually) remunerated to PRPA, while $111.31 million of commercial expenditures are remunerated to PRPA.

When wholesale electricity prices increase, both households and businesses are negatively affected. For households, because electricity demand is highly inelastic, electricity price increases result in larger electric bills, leaving them with less money to spend on other goods

[7] In our simulations we assume that wholesale electricity prices change while all other operating expenses remain constant.

and services. This is, effectively, a reduction in household purchasing power (i.e., a decline in real household income). From a business perspective, when consumers have less to spend, they see lower demand for their goods and services, meaning that they produce less.

Business production decisions are also sensitive to higher electricity prices. Economic theory suggests businesses will reduce their output levels, all else equal, when confronted with rising input prices. *From a regional economic perspective, the upshot of these two impact channels is that higher electricity costs can lead to lower employment and real household income.*

In the first simulation reported in Table 3, we show the impacts of doubling the *wholesale* price of electricity (i.e., 100 percent increase), aggregated across the four municipalities. Because both businesses and households see higher rates, the impacts of higher rates are borne by both groups. Turning first to businesses, we see total regional output (i.e., domestic supply or local GDP) declines by $291.3 million (-1.3 percent). This is due to the idea that higher production costs mean businesses need to increase the price of their good or service, which can result in some loss of market share.

Table 3. Estimated Aggregate Impacts of Various Wholesale Electricity Price Increases

	100% increase		80% increase		60% increase	
	Amount	% Change	Amount	% Change	Amount	% Change
Employment	-1,536	-1.03%	-1,338	-0.90%	-1,102	-0.74%
Real Household Income (mil of $)	-85.0	-0.83%	-74.5	-0.73%	-36.1	-0.77%
Domestic Supply (mil of $)	-291.3	-1.30%	-259.8	-1.16%	-110.5	-0.96%
	40% increase		20% increase		10% increase	
Employment	-830	-0.56%	-472	-0.32%	-254	-0.17%
Real Household Income (mil of $)	-47.1	-0.46%	-27.0	-0.26%	-8.9	-0.19%
Domestic Supply (mil of $)	-169.1	-0.75%	-98.5	-0.44%	-27.8	-0.24%

Turning to households, we see that real household income (i.e., income adjusted for price changes) falls by $85 million (-0.83 percent). This decline is attributed to two factors. First, with higher electricity prices household purchasing power decreases. Second, when local businesses reduce output (as shown above) they demand fewer workers. The lost labor income in the economy is reflected in the decline in household income.

Because of the relative complexity of electricity pricing structures across the municipalities, it is difficult to predict precisely how consumer electricity expenditures will change when wholesale electricity prices increase. Using a demand elasticity of -0.16, however, we estimate that final consumer electricity expenditures will increase in the range of 41 percent (Estes Park) to 52 percent (Fort Collins) when wholesale prices increase 100 percent.[8]

[8] Consumer expenditures in Longmont are estimated to increase by about 51 percent if wholesale electricity prices double, while Loveland's are estimated to increase by roughly 46 percent.

Note that consumer expenditures are not predicted to double, despite a doubling of wholesale prices. This occurs for two reasons. First, as noted above, wholesale electricity purchases account for only about 64 percent of total commercial and household revenues for the four municipal utilities; other expenditures are assumed fixed, meaning *total* production costs will not double. Second, because the demand curve is downward sloping, higher prices will lead to a lower quantity of electricity demanded. Thus, 1) consumer prices will less than double, and 2) the quantity demanded will fall. Together, total expenditures will increase but less than double.

In Tables 4A – 4C we provide the disaggregated results from Table 3, describing municipal-level impacts on employment, real household income and domestic supply. Not surprisingly, the adverse employment impacts are largest in Fort Collins, with total job losses approximately the same as the combined losses in the other three communities in each scenario (Table 4A). However, as a share of total employment, losses are greatest in Longmont in each scenario, suggesting some employers there are slightly more sensitive to electricity price changes (Longmont has a greater share of total employment in high-electricity use manufacturing than does Fort Collins).[9]

Table 4A: Aggregate Distributional Effects (Employment)[10]

	100% increase		80% increase		60% increase	
	Amount	% Change	Amount	% Change	Amount	% Change
Employment						
Longmont	-420	-1.29%	-363	-1.11%	-299	-0.91%
Loveland	-307	-0.95%	-269	-0.83%	-225	-0.69%
Estes Park	-32	-0.94%	-28	-0.82%	-23	-0.68%
Fort Collins	-772	-0.97%	-673	-0.84%	-553	-0.69%
	40% increase		20% increase		10% increase	
Employment						
Longmont	-222	-0.68%	-125	-0.38%	-67	-0.20%
Loveland	-170	-0.52%	-98	-0.30%	-53	-0.16%
Estes Park	-18	-0.52%	-10	-0.30%	-5	-0.16%
Fort Collins	-418	-0.52%	-237	-0.30%	-128	-0.16%

With respect to household income changes, Fort Collins sees the largest negative impact in each price increase simulation, ranging from -1.04 percent (100 percent price increase) to -0.19 percent (10 percent price increase). This highest price increase scenario has a notably smaller,

[9] Longmont is located in Boulder County while Fort Collins, Loveland and Estes Park are located in Larimer County. We use county level data to describe the industrial and commercial structure for the four towns and the Boulder County data has a slightly larger dependence on electricity.

[10] Summing results across individual municipalities may not equal the totals reported in Table 2 due to rounding.

yet similar impact on household income in the other three municipalities, a pattern that holds true across each simulated price increase.[11]

Table 4B: Aggregate Distributional Effects (Real Household Income)

	100% increase		80% increase		60% increase	
	Amount	% Change	Amount	% Change	Amount	% Change
Real Household Income (mil of $)						
Longmont	-19.39	-0.67%	-16.15	-0.56%	-12.72	-0.44%
Loveland	-14.29	-0.62%	-12.73	-0.55%	-10.83	-0.47%
Estes Park	-2.73	-0.68%	-2.44	-0.61%	-2.11	-0.53%
Fort Collins	-48.58	-1.04%	-43.20	-0.93%	-36.12	-0.77%
	40% increase		20% increase		10% increase	
Real Household Income (mil of $)						
Longmont	-9.00	-0.31%	-4.78	-0.17%	-2.48	-0.09%
Loveland	-8.33	-0.36%	-4.93	-0.21%	-2.72	-0.12%
Estes Park	-1.64	-0.41%	-0.98	-0.25%	-0.53	-0.13%
Fort Collins	-28.01	-0.60%	-16.30	-0.35%	-8.94	-0.19%

Examining total domestic production (Table 4C) shows a similar story to total employment. Longmont is most impacted as a share of total output, with losses ranging from 1.58 percent (100 percent price increase) to -0.26 percent (10 percent price increase).

Table 4C: Aggregate Distributional Effects (Domestic Supply)

	100% increase		80% increase		60% increase	
	Amount	% Change	Amount	% Change	Amount	% Change
Domestic Supply (mil of $)						
Longmont	-74.97	-1.58%	-65.67	-1.38%	-54.57	-1.15%
Loveland	-59.32	-1.15%	-53.15	-1.03%	-45.26	-0.88%
Estes Park	-11.74	-1.17%	-10.50	-1.04%	-8.97	-0.89%
Fort Collins	-145.25	-1.26%	-130.44	-1.13%	-110.52	-0.96%
	40% increase		20% increase		10% increase	
Domestic Supply (mil of $)						
Longmont	-41.10	-0.86%	-23.40	-0.49%	-12.61	-0.26%
Loveland	-34.87	-0.68%	-20.48	-0.40%	-11.25	-0.22%
Estes Park	-6.90	-0.69%	-4.05	-0.40%	-2.18	-0.22%
Fort Collins	-86.21	-0.75%	-50.57	-0.44%	-27.77	-0.24%

Because electricity is a necessary good for households, price increases can have important adverse effects, especially on lower income households. In Tables 5A-5D we show the

[11] This is due to a smaller percentage of out commuting in Fort Collins compared to the other municipalities. With a smaller percentage of workers commuting out, a larger percentage of workers who live and work in Fort Collins experience the negative impact of higher electricity prices and thus real household income falls by the largest amount.

distributional impacts within each community for each household "type." Here, our metric is the reduction in real household income (i.e., income adjusted for price changes). As expected, the lowest income earning households (HH1 and HH2) are impacted more negatively than higher earning households (HH3 – HH5) in all price increase scenarios. As an example, for Longmont in the 100 percent case HH1 and HH2 lose respectively 1.31 percent and 1.28 percent, respectively. However, HH5 in Longmont only experiences a 0.49 percent loss in real household income.

Table 5A: Distribution of Real Household Income (Longmont)

	100% increase		80% increase		60% increase	
Real Household Income	Amount (mil of $)	% Change	Amount (mil of $)	% Change	Amount (mil of $)	% Change
HH1 ≤ $15,000	-0.084	-1.31%	-0.069	-1.08%	-0.054	-0.84%
$15,000 < HH2 ≤ $25,000	-0.465	-1.28%	-0.380	-1.04%	-0.292	-0.80%
$25,000 < HH3 ≤ $75,000	-5.104	-1.10%	-4.215	-0.91%	-3.283	-0.71%
$75,000 < HH4 ≤ $100,000	-3.915	-1.07%	-3.281	-0.89%	-2.601	-0.71%
$100,000 < HH5	-9.825	-0.49%	-8.206	-0.41%	-6.492	-0.32%
	40% increase		20% increase		10% increase	
HH1 ≤ $15,000	-0.038	-0.59%	-0.020	-0.31%	-0.010	-0.16%
$15,000 < HH2 ≤ $25,000	-0.201	-0.55%	-0.102	-0.28%	-0.052	-0.14%
$25,000 < HH3 ≤ $75,000	-2.294	-0.50%	-1.196	-0.26%	-0.615	-0.13%
$75,000 < HH4 ≤ $100,000	-1.858	-0.51%	-0.997	-0.27%	-0.521	-0.14%
$100,000 < HH5	-4.613	-0.23%	-2.461	-0.12%	-1.285	-0.06%

Table 5B: Distribution of Real Household Income (Loveland)

	100% increase		80% increase		60% increase	
Real Household Income	Amount (mil of $)	% Change	Amount (mil of $)	% Change	Amount (mil of $)	% Change
HH1 ≤ $15,000	-0.032	-1.37%	-0.027	-1.17%	-0.022	-0.94%
$15,000 < HH2 ≤ $25,000	-0.179	-1.81%	-0.153	-1.54%	-0.124	-1.25%
$25,000 < HH3 ≤ $75,000	-6.656	-1.42%	-5.671	-1.21%	-4.586	-0.98%
$75,000 < HH4 ≤ $100,000	-4.296	-1.39%	-3.739	-1.21%	-3.099	-1.00%
$100,000 < HH5	-3.125	-0.21%	-3.141	-0.21%	-3.005	-0.20%
	40% increase		20% increase		10% increase	
HH1 ≤ $15,000	-0.016	-0.68%	-0.009	-0.38%	-0.005	-0.20%
$15,000 < HH2 ≤ $25,000	-0.090	-0.91%	-0.050	-0.51%	-0.027	-0.27%
$25,000 < HH3 ≤ $75,000	-3.338	-0.71%	-1.857	-0.40%	-0.994	-0.21%
$75,000 < HH4 ≤ $100,000	-2.319	-0.75%	-1.331	-0.43%	-0.724	-0.23%
$100,000 < HH5	-2.565	-0.17%	-1.683	-0.11%	-0.975	-0.06%

Table 5C: Distribution of Real Household Income (Estes Park)

	100% increase		80% increase		60% increase	
Real Household Income	Amount (mil of $)	% Change	Amount (mil of $)	% Change	Amount (mil of $)	% Change
HH1 ≤ $15,000	-0.008	-1.89%	-0.007	-1.59%	-0.006	-1.28%
$15,000 < HH2 ≤ $25,000	-0.038	-2.23%	-0.033	-1.89%	-0.027	-1.54%
$25,000 < HH3 ≤ $75,000	-1.196	-1.42%	-1.017	-1.21%	-0.832	-0.99%
$75,000 < HH4 ≤ $100,000	-0.807	-1.53%	-0.698	-1.32%	-0.580	-1.10%
$100,000 < HH5	-0.678	-0.26%	-0.689	-0.27%	-0.671	-0.26%
	40% increase		20% increase		10% increase	
HH1 ≤ $15,000	-0.004	-0.92%	-0.002	-0.51%	-0.001	-0.26%
$15,000 < HH2 ≤ $25,000	-0.019	-1.12%	-0.011	-0.63%	-0.006	-0.33%
$25,000 < HH3 ≤ $75,000	-0.608	-0.72%	-0.341	-0.41%	-0.179	-0.21%
$75,000 < HH4 ≤ $100,000	-0.432	-0.82%	-0.248	-0.47%	-0.131	-0.25%
$100,000 < HH5	-0.576	-0.22%	-0.380	-0.15%	-0.216	-0.08%

Table 5D: Distribution of Real Household Income (Fort Collins)

	100% increase		80% increase		60% increase	
Real Household Income	Amount (mil of $)	% Change	Amount (mil of $)	% Change	Amount (mil of $)	% Change
HH1 ≤ $15,000	-1.190	-1.61%	-1.005	-1.36%	-0.789	-1.06%
$15,000 < HH2 ≤ $25,000	-1.850	-2.09%	-1.569	-1.77%	-1.239	-1.40%
$25,000 < HH3 ≤ $75,000	-18.074	-1.95%	-15.505	-1.67%	-12.421	-1.34%
$75,000 < HH4 ≤ $100,000	-8.621	-1.44%	-7.529	-1.26%	-6.165	-1.03%
$100,000 < HH5	-18.846	-0.63%	-17.597	-0.59%	-15.505	-0.52%
	40% increase		20% increase		10% increase	
HH1 ≤ $15,000	-0.575	-0.78%	-0.309	-0.42%	-0.163	-0.22%
$15,000 < HH2 ≤ $25,000	-0.907	-1.02%	-0.492	-0.55%	-0.260	-0.29%
$25,000 < HH3 ≤ $75,000	-9.223	-0.99%	-5.096	-0.55%	-2.720	-0.29%
$75,000 < HH4 ≤ $100,000	-4.680	-0.78%	-2.659	-0.44%	-1.440	-0.24%
$100,000 < HH5	-12.620	-0.42%	-7.747	-0.26%	-4.356	-0.15%

Our final set of analyses focuses on the impacts on commercial and industrial sectors and how they respond to changes in electricity rates. Table 6 shows how these sectors might be impacted by a 100 percent increase, while Table 7 shows the 10 percent price increase scenario.

Table 6: Percentage loss in Output for Selected Commercial Sectors for the 100% Increase in Electricity Prices

	Longmont	Loveland	Fort Collins	Estes Park
Retail	-0.82%	-0.54%	-0.61%	-0.33%
Services	-1.13%	-0.80%	-0.93%	-0.84%
Real Estate	-2.08%	-0.73%	-0.76%	-0.51%
Construction	-1.20%	-0.81%	-0.85%	-0.62%
Health	-0.38%	-0.25%	-0.34%	0.14%
Accommodations	-0.33%	-0.05%	-0.07%	0.02%
Other	-0.75%	-0.47%	-0.46%	-0.02%
Manufacturing (High use)	-1.72%	-0.17%	-0.27%	-0.41%
Manufacturing (Medium use)	-0.36%	-0.05%	-0.05%	-0.19%
Manufacturing (Low use)	-0.15%	0.00%	-0.03%	-0.11%

In general, our results show that the retail, services, real estate[12] and construction sectors are most impacted by the 100 percent increase in electricity prices. These sectors primarily sell their output to local households, and since real household income is falling, it is expected that the local sectors would be hurt the most.

[12] Real estate includes ownership and management of rental units, including apartment complexes. Because some rental property owners include electricity as part of the rent they charge, electricity expenditures for the real estate sector are higher than might otherwise be expected given the generic name of the sector.

It is interesting to note that even though the manufacturing sector tends to consume a lot of electricity, the output loss is much smaller in percentage terms than it is for the local sectors. This is due to the fact that manufacturers tend to export most of their output rather than sell to local consumers. Thus, there is no real demand impact of lower local real household income. Instead, the only reason the manufacturing sectors lose output is due to their relative prices rising slightly due to the increase in electricity prices. Not surprisingly, the higher the use of electricity in the high use category of manufacturing sectors results in a larger loss of output.

Table 7: Percentage loss in Output for Selected Commercial Sectors for the 10% Increase in Electricity Prices

Sector	Longmont	Loveland	Fort Collins	Estes Park
Retail	-0.10%	-0.09%	-0.09%	-0.05%
Services	-0.23%	-0.16%	-0.18%	-0.19%
Real Estate	-0.31%	-0.15%	-0.14%	-0.11%
Construction	-0.24%	-0.15%	-0.16%	-0.13%
Health	0.00%	-0.01%	-0.01%	0.06%
Accommodations	0.00%	0.02%	0.03%	0.02%
Other	-0.09%	-0.08%	-0.06%	0.02%
Manufacturing (High use)	-0.25%	0.00%	-0.05%	-0.10%
Manufacturing (Medium use)	-0.05%	0.00%	0.01%	-0.04%
Manufacturing (Low use)	0.00%	0.02%	0.01%	-0.03%

Putting the employment results in context

The magnitude of the job impacts (Tables 3 and 4A) can be better understood when putting them in context of historic regional economic performance. In Table 8, we use data from the Colorado Department of Labor and Employment (CDLE) to show how average annual employment totals in the four municipalities changed over the period 2007-2015. The data shown here is the annual average of the one-year, quarterly change (e.g., the first quarter of 2014 versus 2015). For example, the average growth in quarterly total employment from the previous year in Estes Park totaled 272 jobs between 2014 and 2015.

Aggregating the job changes across the four municipalities shows that they added a total of 5,465 jobs between 2014 and 2015. Evaluating the employment simulation results for a 100 percent increase in wholesale electricity prices shows that the job losses across the municipalities (1,536) would have offset about 28.1 percent of the employment gains. Note that this is a one-time, but permanent effect; after the initial shock the economy would be expected to "normally" grow, yet from a lower-baseline.

By looking back in time, we also can see how the impacts would compare to job losses the region suffered during the "Great Recession" (December 2007-June 2009). For the four municipalities, the brunt of the recession was felt between 2008 and 2009, with more than 5,700 jobs lost. Simulated job losses due to the 100 percent wholesale electricity price increase would represent about 27 percent of the jobs lost during the worst year of the last recession.

Table 8: Actual Employment Changes for the Four Towns

Year	Estes Park	Fort Collins	Longmont	Loveland	Total
2007	(86)	1,906	628	1,340	3,788
2008	142	976	305	270	1,693
2009	(80)	(1,601)	(2,875)	(1,178)	(5,733)
2010	(195)	567	(510)	(49)	(188)
2011	(98)	1,782	684	393	2,761
2012	129	800	1,256	1,345	3,530
2013	(28)	2,275	1,273	1,575	5,095
2014	182	2,992	2,838	1,335	7,346
2015	272	3,028	833	1,331	5,465

An additional perspective is to understand the relative importance of electricity demand in the budget for five sectors in each of the four towns, retail, services, manufacturing (High Use), manufacturing (medium use) and manufacturing (low use). Longmont is designated as LG, Loveland as LV, Estes Park as EP and Fort Collins as FC. As an example, the sector LGmanufH is manufacturing in Longmont that is a high user of electricity. Table 9 presents the relative importance of electricity and wage payments for each of the five selected. It is clear from Table 9 that electricity payments are a relatively low percentage of all budgets.

Table 9: Relative Importance of Electricity and Wages Payments for Selected Sectors

	LGretail	LGserv	LGManufH	LGmanufM	LGmanufL
Percent of Budget for Electricity	1.5%	0.3%	7.2%	2.9%	1.2%
Percent of Budget for Wages	24.8%	17.6%	37.1%	36.5%	36.2%
	LVretail	LVserv	LVManufH	LVIManufM	LVManufL
Percent of Budget for Electricity	0.7%	0.3%	5.2%	2.1%	0.8%
Percent of Budget for Wages	39.4%	21.7%	39.6%	38.6%	38.1%
	EPretail	EPserv	EPManufH	EPManufM	EPManufL
Percent of Budget for Electricity	1.0%	0.3%	6.9%	2.7%	0.8%
Percent of Budget for Wages	20.0%	50.0%	11.7%	9.7%	8.7%
	FCretail	FCserv	FCManufH	FCManufM	FCManufL
Percent of Budget for Electricity	1.2%	0.2%	6.2%	2.5%	1.0%
Percent of Budget for Wages	30.4%	32.6%	27.1%	26.1%	26.0%

Appendix A: Characteristics of the Four Towns

In our analysis we develop individual models for each utility service area of interest: Estes Park[13], Fort Collins, Longmont and Loveland. The models are linked through their relationship with PRPA as the wholesale electricity provider. In conjunction with information provided by the individual utilities on the number of their residential customers, we use data from the US Census Bureau to distinguish residential users by annual income (i.e., household type). Table A1 presents the number of residential customers in each income classification for each utility service area.

Table A1: Number of Households, by Type and Municipality

Households	Estes Park	Ft Collins	Longmont	Loveland
HH1 ≤ \$15,000	274	7,137	3,219	2,362
\$15,000 < HH2 ≤ \$25,000	1,164	6,171	3,079	3,061
\$25,000 < HH3 ≤ \$75,000	2,593	23,249	14,056	13,561
\$75,000 < HH4 ≤ \$100,000	959	8,190	4,465	4,595
\$100,000 < HH5	1,206	15,385	9,719	6,690
Total	6,196	60,132	34,538	30,269

Businesses in each service area have been aggregated into the sectors shown in Table A2. We have divided the manufacturing firms into high, medium and low users of electricity.

Table A2: Employment in Aggregated Sectors for the Four Municipalities

	Estes Park	Fort Collins	Longmont	Loveland
Electricity	25	108	100	136
Utilities	15	278	233	44
Retail	521	8,139	3,791	5,050
Services	636	32,385	12,242	7,362
Real Estate	159	1,745	529	560
Construction	130	2,312	997	1,962
Health	531	12,279	5,088	5,254
Accommodations	1,198	10,391	3,767	4,400
Other	95	1,467	1,318	1,745
Manufacturing(H)	71	7256	3,840	4,852
Manufacturing(M)	7	735	388	491
Manufacturing(L)	5	159	84	106
Total	3,393	77,254	32,377	31,962

[13] The Estes Park electric utility customer base includes not only the Town of Estes Park, but also Allenspark, Glen Haven and other outlying areas. The Estes Park utilities website reports that they have 6,196 residential customers, a much larger number of households than identified by the US Census Bureau for Estes Park itself, so we elected to model how all these households are affected by changes in electricity prices.

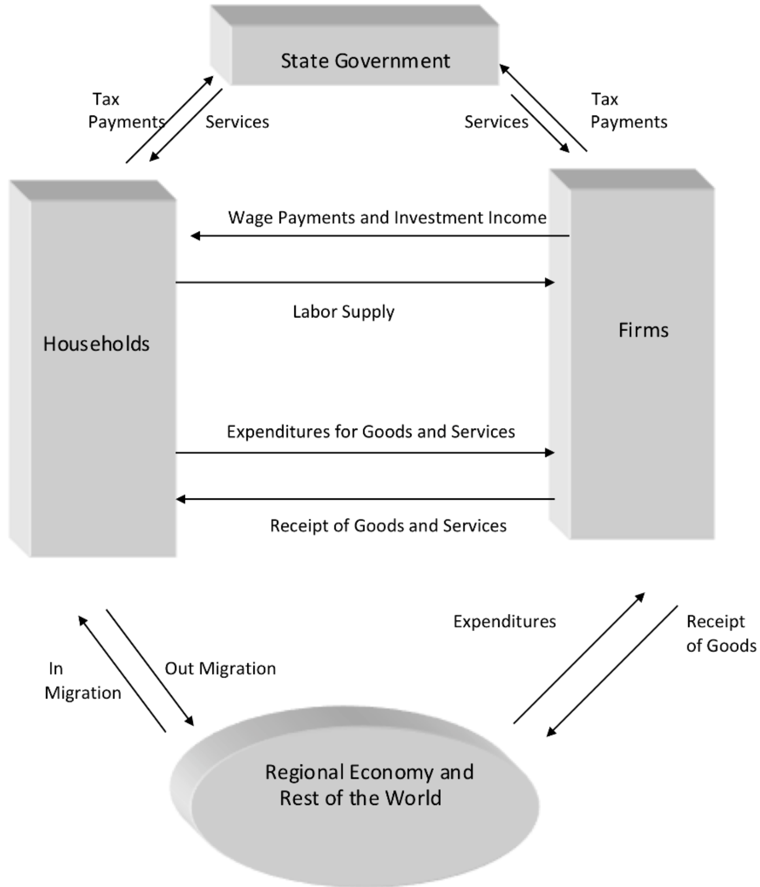
Appendix B: The Four Region CGE Model

The economic impact analysis is based on simulation results from a computable general equilibrium (CGE) model of the regional economy. Today, CGE models are the preferred tool for regional impact analysis because they are founded in microeconomic theory, with outcomes driven by the resource allocation decisions of utility maximizing households and profit maximizing firms. Accordingly, CGE models have often supplanted more traditional input-output (IO) impact models that do not rely on these behavioral relationships. CGE models fully incorporate prices into the analysis, addressing the largest shortcoming of the I-O model and thus reflecting a more realistic portrayal of the "real world."

Figure B1 presents a schematic of the CGE model, where the interaction between households, private sectors, the local government and the regional economy is shown. The box labeled households represents all families who live in the region, in either single residential homes or multiple unit dwellings. This block contains five household groups differentiated by income. The local supply of labor comes directly from these household groups and is determined by elasticities of labor supply for each household. Labor supply can also change by households migrating into or out of the region depending on changes in relative economic conditions. The flow of income is represented by the arrows from firms and governments to the households, and includes wage payments, capital and land income and transfer payments. Utility maximizing households then spend their income on goods, services, and housing.
Firms are grouped into 12 production sectors that hire labor and purchase physical capital and land. We assume that firms maximize profits.

A series of equations are used to represent the flow of wages, capital and land income, and the production of goods in Figure B1. Altogether, there are more than 1,000 equations in the model. The model is calibrated when the equations exactly reproduce the base data in the social accounting matrix and the quantities of labor and land.

Figure B.1: Circular Flow Diagram of Regional Economy



Description of Data

The Colorado Department of Labor and Employment, US Bureau of Labor Statistics and US Census Bureau are our main data sources. Important data points include employment and wages, by industry, regional commuting patterns, and household demographic data. Relevant data for modeling the production side of the economy is obtained from the Bureau of Economic Analysis and IMPLAN. Data from these sources are then used to create a distribution of employment and wages by sector and also help calculate income earned by households.

The wage and employment data, when combined with data for land and capital, provide high quality representations for each sector in the regional economy. On a more technical note, we are able to generate production functions for each sector that are better specified than most other models.

The labor, land and capital income can be mapped into the five different household groups in order to derive expenditure patterns for all households. The calculation of household expenditures across sectors requires both the distribution of expenditures as well as the level of expenditures. Distribution patterns were estimated using data from the *Consumer Expenditure Survey* from the US Bureau of Labor Statistics.

Our model also draws on information from PRPA, the *Consolidated Annual Financial Report* of the four municipalities, and published reports and website information for the four utilities. This information allows us to better model the utility sector for each municipality.

Appendix C: Varying Elasticity Demands for Electricity

Economic theory (and empirical evidence) shows that, as time passes, commodity price changes have a diminishing impact on consumers and businesses because they are better able to seek out and employ substitutes. For example, when the price of gasoline increases significantly, consumers are often initially hard hit. In the longer-run, however, commuters can join car pools, switch to alternative transportation modes, or even buy more fuel efficient vehicles. The end result is a substantial reduction in gasoline purchases. It is reasonable to expect similar behavior when electricity prices increase. Yet examining the response to an increase in the price of electricity over the long-run requires that the alternatives to electricity usage be identified, a complex objective. We consider this from the perspective of both households and firms.

In the immediate aftermath of a price increase, consumers may be expected to use less electricity through simple measures, such as making sure to turn off lights when leaving a room. Such behavioral changes are captured in our model in the short-run own-price demand elasticity estimates. In the long-run, a household responding to higher electricity prices may adopt alternative technologies such as more efficient light bulbs and appliances that use less electricity.[14] Modeling such behavioral changes is difficult because we would need estimates on how many households would engage in such behavior and their expenditures on such purchases. A second potential household behavior house is to pursue alternative electricity sources, such as installing solar panels on their roof. To model this behavior, we would need estimates of how many households would engage in this type of purchase and the cost of installing solar energy. Properly modeling these longer run ideas would entail a separate research project.

A firm's long-run response to higher electricity prices is similarly complex. One potential response would be for businesses to purchase more efficient capital such as new machines and tools, new lighting systems, etc.[15] It is likely that these new capital purchases would also me more technologically advanced, with the impacts of associated productivity gains necessarily modeled as well. For example, a new tool may not only use less electricity but it also may make workers more productive. Any analysis of this type would be a significant challenge. In terms of firms finding alternative electricity sources, the current technology suggest firms could adopt more roof-top solar, introducing modeling challenges similar to those on the household side.

Despite the significant challenges of modeling long-run behavioral changes, we have run a number of simulations using larger own-price demand elasticities for firms and households to

[14] For example, see Rapson (2014). "Durable goods and long-run electricity demand: Evidence from air conditioner purchase behavior." Journal of Environmental Economics and Management 68:141-160.
[15] For an example of recent research in this area see Sanguk et al. (2016). "Short-run and the long-run effects of electricity price on electricity intensity across regions." Applied Energy 172:372-382.

represent more flexibility in responding to higher electricity prices (discussed below). However, we have not taken into account the substitutes to electricity that would have to be purchased as well as the potential productivity gains that could be realized. For firms, a larger reduction in electricity demand (i.e., a greater price elasticity) will lead to slightly larger decreases in overall economic activity. This is due to a greater reduction in electricity use, which reduces the ability of firms to produce goods and services when it is a necessary input. If we were able to model the efficiency gains then the long-run impact could be less negative. For households, a larger reduction in electricity demanded in the long-run will lead to a smaller reduction in economic activity since households can avoid the more costly electricity expenditures, freeing up some money to spend on other goods and services. However, we have not taken into account finding the substitutes for electricity.

In our main analysis we describe the impacts of energy price changes when assuming an own-price elasticity of -0.16 (highly inelastic) for households and an own-price elasticity of -0.22 for firms, short-term results commonly demonstrated in previous empirical literature. However, it is worth looking at how our results change should consumer and firm electricity demand be more sensitive to its price. In Table C1 we provide results from some of the alternative simulations, where we increase the elasticity of demand to -0.5.[16] Our analysis shown here is based on a 100 percent increase in electricity prices. Results with smaller price increases are less different from the simulations in the main section of the report.

Table C1: Estimates of Aggregate Impacts of 100 percent Price Increase Under Various Elasticities

	(a) -0.16 HH and -0.22 firms		(b) -0.5 for HH and firms		(c) -0.5 firms/-0.16 HH		(d) -0.5 HH and -0.22 firms	
Employment	-1535.7	-1.03%	-1917.0	-1.28%	-2062.4	-1.38%	-1391.3	-0.93%
Real HH Income	-85.0	-0.83%	-119.9	-1.17%	-74.9	-1.60%	-77.2	-0.75%
Domestic Supply	-291.3	-1.30%	-373.1	-1.66%	-185.3	-1.60%	-140.0	-1.21%

Note: real household income and domestic supply are measured in millions of dollars.

The first two data columns (a) of the table repeat the results of the 100 percent increase with the -0.16 elasticity, aggregated across the four municipalities. In this scenario, employment fell by 1,535 jobs (-1.03 percent), real household income fell by $85 million (-0.83 percent), and domestic supply fell by $291.3 million (1.30 percent). In the second simulation (b) we assume households and firms each have a price elasticity of demand of -0.5 (this is at the upper end of most empirical estimates of the long-run price elasticity of demand). In this scenario, employment, real household income and domestic supply all fall by larger amounts than in the baseline case, declining by -1.28 percent, -1.17 percent and -1.66 percent, respectively.

[16] One recent study estimates the long-run price elasticity of demand as -0.29: Deryugina, T., A. MacKay, A., and J Reif (2017). "The Long-Run Elasticity of Electricity Demand: Evidence from Municipal Electric Aggregation" (https://www.econ.pitt.edu/sites/default/files/Deryugina.Electricity%20Aggregation.pdf)

To better understand the differential impacts on firms and households, we ran two additional simulations. In (c) we increase the price elasticity of demand to -0.5 for firms, and leave it at -0.16 for households. Here we see than total employment and domestic supply losses increase relative to (b), suggesting that firms are especially susceptible to price increases. This is confirmed by (d), which shows that, under a -0.5 household elasticity/-0.16 firm elasticity, employment losses are actually smaller than in the baseline case. The basic intuition of the result is that households respond to higher electricity prices by consuming less electricity and spending more on other goods and services. In contrast, firms find it difficult to substitute into other inputs, thus their response is simply to reduce output.

Appendix D: Results for a 10 and 20 Percent Reduction in Electricity Prices

Tables D1 – D8 present scenarios where electricity prices fall by 10 and 20 percent. These scenarios could potentially occur in the future.

Table D1. Estimated Aggregate Impacts of Various Wholesale Electricity Price Increases

	10% Decrease		20% Decrease	
	Amount	% Change	Amount	% Change
Employment	302.3	0.20%	667.6	0.45%
Real Household Income (mil of $)	11.0	0.24%	39.7	0.39%
Domestic Supply (mil of $)	34.3	0.30%	146.6	0.65%

Table D2: Aggregate Distributional Effects (Employment)[17]

	10% Decrease		20% Decrease	
	Amount	% Change	Amount	% Change
Employment				
Longmont	78.0	0.24%	170.8	0.52%
Loveland	64.2	0.20%	142.3	0.44%
Estes Park	6.5	0.19%	14.4	0.42%
Fort Collins	152.8	0.19%	338.4	0.42%

Table D3: Aggregate Distributional Effects (Real Household Income)

	10% Decrease		20% Decrease	
	Amount	% Change	Amount	% Change
Real Household Income (mil of $)				
Longmont	2.73	0.09%	5.798	0.20%
Loveland	3.37	0.15%	7.578	0.33%
Estes Park	0.665	0.17%	1.509	0.38%
Fort Collins	11.03	0.24%	24.859	0.53%

Table D4: Aggregate Distributional Effects (Domestic Supply)

	10% Decrease		20% Decrease	
	Amount	% Change	Amount	% Change
Domestic Supply (mil of $)				
Longmont	14.94	0.31%	32.93	0.69%
Loveland	13.71	0.27%	30.45	0.59%
Estes Park	2.63	0.26%	5.89	0.59%
Fort Collins	34.31	0.30%	77.33	0.67%

[17] Summing results across individual municipalities may not equal the totals reported in Table 2 due to rounding.

Table D5: Distribution of Real Household Income (Longmont)

	10% Decrease		20% Decrease	
Real Household Income	Amount (mil of $)	% Change	Amount (mil of $)	% Change
HH1 ≤ $15,000	0.011	0.17%	0.023	0.35%
$15,000 < HH2 ≤ $25,000	0.054	0.15%	0.110	0.30%
$25,000 < HH3 ≤ $75,000	0.657	0.14%	1.367	0.29%
$75,000 < HH4 ≤ $100,000	0.581	0.16%	1.244	0.34%
$100,000 < HH5	1.428	0.07%	3.055	0.15%

Table D6: Distribution of Real Household Income (Loveland)

	10% Decrease		20% Decrease	
Real Household Income	Amount (mil of $)	% Change	Amount (mil of $)	% Change
HH1 ≤ $15,000	0.005	0.23%	0.011	0.49%
$15,000 < HH2 ≤ $25,000	0.031	0.31%	0.066	0.67%
$25,000 < HH3 ≤ $75,000	1.146	0.24%	2.475	0.53%
$75,000 < HH4 ≤ $100,000	0.867	0.28%	1.914	0.62%
$100,000 < HH5	1.324	0.09%	3.111	0.21%

Table D7: Distribution of Real Household Income (Fort Collins)

	10% Decrease		20% Decrease	
Real Household Income	Amount (mil of $)	% Change	Amount (mil of $)	% Change
HH1 ≤ $15,000	0.184	0.25%	0.395	0.53%
$15,000 < HH2 ≤ $25,000	0.296	0.33%	0.639	0.72%
$25,000 < HH3 ≤ $75,000	3.165	0.34%	6.914	0.74%
$75,000 < HH4 ≤ $100,000	1.729	0.29%	3.842	0.64%
$100,000 < HH5	5.652	0.19%	13.069	0.44%

Table D8: Distribution of Real Household Income (Estes Park)

	10% Decrease		20% Decrease	
Real Household Income	Amount (mil of $)	% Change	Amount (mil of $)	% Change
HH1 ≤ $15,000	0.007	1.50%	0.003	0.66%
$15,000 < HH2 ≤ $25,000	0.006	0.38%	0.014	0.83%
$25,000 < HH3 ≤ $75,000	0.206	0.25%	0.455	0.54%
$75,000 < HH4 ≤ $100,000	0.155	0.29%	0.346	0.66%
$100,000 < HH5	0.290	0.11%	0.690	0.27%