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Cost Savings and CO_2 Emissions Reductions of Residential Electrification in Peoples Gas Territory

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Chapter 1 Executive Summary

Many studies have concluded that decarbonizing buildings through electrification of space heating, water heating and other end uses will be required in order to achieve the level of deep reductions in greenhouse gas emissions by 2050 that are necessary to avoid catastrophic climate change. Electrifying buildings will likely take decades, which means electrification efforts must begin now. Understanding how and where to begin – which buildings are the best candidates for electrification *today* – requires an understanding of the potential impacts of electrification investments on energy bills, given current and expected near term changes in energy prices, and greenhouse gas emissions, given the current and expected near term transition to a cleaner electric grid.

This report provides an in-depth analysis of electrification of single-family homes and individually metered multi-family apartments with forced air heating systems in Peoples Gas' service territory in Chicago, Illinois. The primary focus is on the financial impacts on homeowners,[1] including both capital costs for equipment and appliances and energy bill impacts given current and expected future retail energy prices. We also assess the carbon emission impacts of electrification.

The analysis assumes conversions occurring in 2023 and looks forward twenty years to assess longer-term costs and emissions. Note that we expect several trends will make the cost and the emissions impacts of electrification that we document in this report for 2023 conversions to be more favorable in the future. As markets for electric technologies grow, we expect the initial capital costs for cold climate air source heat pumps and other electric equipment to decline, while their efficiency and other performance features continue to improve. We also expect the electric grid to continue to become cleaner, both because of national market trends and because of emission reduction requirements of Illinois' recently passed Climate and Equitable Jobs Act (CEJA). While our report does not assess the potential for such changes to

[1] The analysis could also be interpreted as addressing impacts on renters, to the extent that the capital costs of electrification are indirectly included in rents.

affect the cost or environmental impacts of an electrification decision in 2025, 2030 or any other future year, future analyses should address these changes.

Our analysis focuses most heavily on space heating electrification, but also addresses water heating, cooking and drying in some circumstances. The economics and environmental impacts are addressed across a range of potential electrification investment decision points. They include:

- **New construction** – we assume all end uses are met with electricity.
- **Existing buildings, full electrification at the time of HVAC replacement**– purchase and installation of a heat pump, heat pump water heater, induction stove and electric dryer at the time an existing gas furnace and central A/C would have otherwise been replaced (we assume the furnace and central A/C would be replaced together).
- **Existing buildings, space heating electrification at the time of HVAC replacement** – purchase and installation of a heat pump at the time an existing gas furnace and existing central A/C system would have otherwise been replaced (we assume the furnace and central A/C would be replaced together).
- **Existing buildings, water heating electrification at the time of domestic water heater (DHW) replacement** – purchase and installation of a heat pump water heater at the time an existing gas water heater would otherwise have been replaced.

These decision points are depicted in Table 1 below:

Table 1: Electrification Decision Points

Vintage	Full or Partial Electrification	Decision Point	End Uses Addressed			
			Heating & Cooling	Hot Water	Drying	Cooking
New	Full	Design/Construction	X	X	X	X
Existing	Full	Time of Replacement - HVAC	X	X	X	X
Existing	Partial	Time of Replacement - HVAC	X			
Existing	Partial	Time of Replacement - DHW		X		

The analysis required a variety of data and assumptions regarding residential energy consumption for space heating, water heating, cooling, cooking and drying; capital costs and efficiencies of different electric and gas equipment; current retail electric and gas energy prices and how they will change over the next twenty years; and both current and future CO_2 emission rates for fossil gas and the electric grid. We also considered costs both with and without the federal Inflation Reduction Act rebates or tax credits for electrification measures.

Cost-Effectiveness of Electrification

The impacts of electrification on household costs are summarized in Table 2 and Table 3. The first section of each table shows total energy cost savings – the combined impact of both (A) changes in capital costs for heating, water heating and other end use equipment; and (B) changes in energy bills over the next twenty years. Values are expressed in net present value (NPV) terms. The second section shows just energy bill savings in just the first year after electrification takes place.

Table 2: Single-Family Cost Savings from Electrification (2022 $)

	All Electric New Construction	Existing Home Full Electrification	Existing Home Heating Electrification	Existing Home Water Heat Electrification
20-Year NPVs of Total Cost Savings from Electrification (Capital + Energy)				
Without Federal Incentives	**$20,192**	**$13,351**	**$8,976**	**$1,361**
With IRA Low Income Rebate	**$31,436**	**$24,594**	**$16,976**	**$3,111**
With IRA Moderate Income Rebate	**$25,814**	**$18,973**	**$12,976**	**$2,236**
With IRA Tax Credits	**$22,946**	**$16,104**	**$10,976**	**$2,115**
1st Year Energy Bill Savings from Electrification				
	$1,445	**$1,445**	**$941**	**$165**

Table 3: Multi-Family Cost-Savings from Electrification (2022 $)

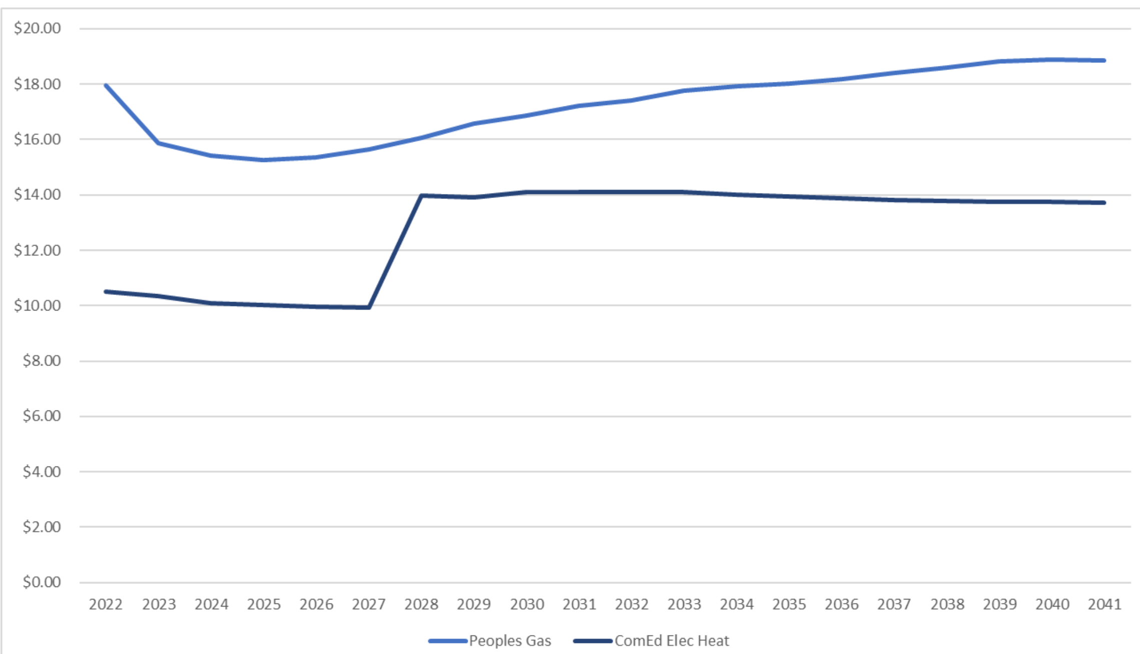
	All Electric New Construction	Existing Home Full Electrification	Existing Home Heating Electrification	Existing Home Water Heat Electrification
20-Year NPVs of Total Cost Savings from Electrification (Capital + Energy)				
Without Federal Incentives	**$15,299**	**$10,889**	**$7,373**	**$711**
With IRA Low Income Rebate	**$24,978**	**$20,569**	**$13,809**	**$2,461**
With IRA Moderate Income Rebate	**$20,138**	**$15,729**	**$10,591**	**$1,586**
With IRA Tax Credits	**$17,983**	**$13,574**	**$9,304**	**$1,464**
1st Year Energy Bill Savings from Electrification				
	$1,036	**$1,036**	**$605**	**$114**

As both tables show, residential electrification in Peoples Gas territory will save families a lot of money over our twenty-year analysis period. That is the case even without any federal incentives (the first row). When federal Inflation Reduction Act (IRA) rebates and/or tax credits are applied, even greater savings are realized. The impact of the IRA incentives is greatest for low-income households – those whose incomes are at or below 80% of area median income – because the IRA incentives are largest for such households (e.g., up to $8,000 for a heat pump and up to $1,750 for a heat pump water heater). As the last row in both tables also shows, households which electrify will see reductions in their energy bills in the very first year. In other words, the cost-effectiveness of electrification is not predicated on assumptions about gas prices rising faster than electricity energy prices.

While all forms of electrification will reduce costs, space heating electrification (20-year savings ranging from over $7,000 to nearly $17,000, depending on building type and IRA incentive eligibility) provides greater savings than water heating electrification (20-year savings ranging from about $700 to over $3,000). There are several reasons for this. First, as shown in Figure 1, after accounting for differences in the efficiency of gas and electric equipment, ComEd's electric rates are lower (per unit of heat provided) than Peoples Gas' gas rates. That is true both today and in the future. It is primarily a function of substantial regional and national increases in the wholesale cost of gas and the significant additional costs that households are now paying through the Qualified Infrastructure Plant (QIP) surcharge on their Peoples Gas bills for the utility's investments in replacing the pipes it uses to bring gas to homes and businesses.

Since space heating requires more energy than water heating, the total annual bill savings are greater for space heating. Second, electrification of space heating allows homeowners and renters to switch to ComEd's lower cost electric heat rate which saves money not only on their heating bill but also on all other uses of electricity (e.g., lighting, refrigeration, computers, TVs, etc.). Third, space heating electrification allows households to pay lower fixed monthly charges for the gas they may still use for cooking, drying, water heating or other uses. This benefit is particularly important because the fixed monthly cost on Peoples Gas bills has also grown substantially as a result of increasing QIP surcharges. Fourth, cold climate heat pumps are significantly more efficient in cooling mode than the central air conditioners that they replace, providing additional cooling cost savings.

Figure 1: Variable Single-Family Energy Costs per Unit of Heat (2022 $/MMBtu)[2]



[2] Variable costs per unit of heat output are the variable portion of gas and electric bills – i.e., the portion of bills that vary with the number of gas therms or electric kWh consumed – divided by assumed efficiencies of gas and electric heating equipment. We assume 92% efficient gas furnaces and electric heat pumps with average annual coefficients of performance (COPs) of 2.6. The electric costs depicted in this graph are for ComEd's electric heating rate. Note that we assume the ComEd rate will increase by nearly four cents per kWh in 2028 because the "carbon-free energy resource adjustment" on its electric bills is expected to expire after 2027. A detailed discussion of current gas and electric rates and how we forecast that they will change can be found in Chapter 3 of this report.

It should also be noted that full electrification of existing homes – in which all gas uses are converted to electricity – produces between $3,500 and $7,600 more cost savings than just space heating electrification. This is mainly because full electrification allows households to eliminate *all* fixed monthly charges for gas. Although there are additional capital costs associated with full electrification (e.g., replacing gas stoves and dryers), the value of avoiding all fixed monthly charges on gas bills significantly outweighs those added capital costs.

All electric new construction provides even greater cost savings than full electrification of existing homes. Part of the reason is that in new construction one only needs to incur the incremental cost of upgrading from a gas cooking and drying appliances to electric ones (rather than the full cost of replacing gas stoves and dryers in an existing home). More important is the ability to avoid substantial costs associated with both running gas pipes within the home and connecting to the gas utility's distribution system.

Several caveats about this analysis are worth noting:

- **Results are for the average home**. Our analysis is based on the average single-family home and the average multi-family apartment served by Peoples Gas. However, sensitivity analyses suggest that electrification of space heating will save households money even if they consume substantially less or more than average.
- **No building efficiency improvements assumed.** To the extent that there are cost-effective opportunities to reduce air leakage, increase insulation and/or make other efficiency improvements to a home, such investments will lower energy bills while also providing comfort and other non-energy benefits. Of course, this would be true whether a gas-heated home continued to burn gas or whether it is electrified. However, if efficiency upgrades are made at the same time as electrification, they could enable a smaller new heat pump to be installed, lowering the initial incremental capital cost required for electrification.
- **Assumption that no electric panel upgrades are necessary**. The results we are presenting are for homes for which no electric panel upgrades are necessary to enable electrification. However, as Table 2 and Table 3 both show, even if electric panel

upgrades are needed, that would not change our conclusions about the typical cost-effectiveness of electrification. For example, our estimate of $13,351 in total cost savings over 20 years from fully electrifying a single-family home (excluding IRA incentives) would decline to a still very substantial $10,851 if the electric panel upgrade cost was $2,500. Moreover, the federal IRA rebates will cover all of the cost of such electric panel upgrades for low-income households and half of such costs for moderate income households.

- **HVAC time-of-replacement scenario assumes both furnace and central air conditioner would otherwise be replaced together**. The cost-effectiveness of space heating electrification would be a little lower if the household was planning to replace only its furnace or only its central air conditioner. Even if that was the case, it would still be very cost-effective to electrify. For example, if only the furnace would otherwise have been replaced, the total cost savings over twenty years from full electrification of a single-family home would still be $10,665 (without IRA rebates).
- **Excludes benefits of ComEd and/or City of Chicago financial incentives**. Our analysis does not account for any additional cost reductions that households may realize from rebates for electrification measures beyond those provided by the federal IRA.[3] Any ComEd or City of Chicago rebates will increase total cost savings.
- **Potentially conservative assumptions about future gas prices**. Our estimates of the rate at which gas and electricity prices will increase in the future are based primarily on the U.S. Energy Information Administration's (EIA's) 2022 Annual Energy Outlook (AEO) for the East North Central region (which includes Illinois).[4] Current prices in futures markets for gas suggest that prices will be a little higher over the next five years than forecast by EIA. We decided to use EIA's forecast so that the source we reference for future price changes is consistent for both gas and electricity. To the extent that future

[3] Illinois households should be able to access federal IRA electrification rebates. However, that is contingent on the state of Illinois submitting a plan for how it will disperse them to the U.S. Department of Energy and having that plan approved.

[4] The only adjustment we made to the EIA 2022 AEO escalation rates was to account for the significant additional capital expenditures for gas pipe replacements forecast for Peoples Gas' "Safety Modernization Program".

gas price increases are more in line with current futures markets than EIA's 2022 AEO forecast, electrification will likely be more cost-effective than our analysis suggests.[5]

- **5% real discount rate used for NPV calculations.**[6] Sensitivity analyses suggest that electrification is cost-effective under any reasonable assumption about the real discount rate. For example, the $13,351 total cost savings for full electrification of existing homes – without any federal incentives – increases to about $21,000 with a 1% real discount rate (comparable to the societal discount rate ComEd, Peoples Gas and other Illinois utilities use to assess the cost-effectiveness of their efficiency programs) and declines to a little under $8,000 with a 10% real discount rate.

Carbon Emission Impacts of Electrification

Electrification displaces carbon emissions associated with on-site combustion of natural gas and increases carbon emissions from the electric grid. The magnitude of increased grid emissions is a function of the cleanliness of the grid. Any assessment of the net effect on emissions needs to consider not only the difference in emissions in the first year, but the difference over the expected life of the electric heat pump, heat pump water heater and other electric appliances. This is important because the grid has been getting cleaner and is expected to continue to get cleaner.

As Table 4 and Table 5 show, electrification will produce substantial CO_2 emissions reductions. As one would expect, the tons of emission reductions (last row of each table) are greatest for full electrification, almost as large for just space heating electrification because space heating accounts for the lion's share of gas use in most homes, and smallest for water heating. However, the percent reductions are largest for water heating because the efficiency difference between gas and electric water heating equipment (63% for gas, 280% for electric) is bigger than for space heating (92% for gas, 260% for electric). Note also that these are just direct carbon

[5] Note that gas prices will also have some effect on future electricity prices.

[6] Discount rates are used to assign a time preference for money. The higher the discount rate, the higher the implied preference for money this year instead of next year or any subsequent year. Real discount rates are already adjusted to remove the impacts of inflation. For example, a 5% real discount rate is equivalent to 8.2% discount rate if long-term inflation is projected to average 3% per year. Thus, a real discount rate reflects a time preference for money even if there was no inflation.

emission reductions from combustion. We have not estimated the lifecycle emission reductions associated with fossil gas production and transportation as well as combustion.

Table 4: Single-Family CO_2 Emissions Reductions Across End Uses Electrified

	All Electric New Construction	Existing Home Full Electrification	Existing Home Heating Electrification	Existing Home Water Heat Electrification
1st Year % Reduction	30%	30%	28%	56%
20-Year % Reduction	52%	52%	50%	71%
20-Year Tons of Reduction per Home	78	78	57	18

Table 5: Multi-Family CO_2 Emissions Reductions Across End Uses Electrified

	All Electric New Construction	Existing Home Full Electrification	Existing Home Heating Electrification	Existing Home Water Heat Electrification
1st Year % Reduction	31%	31%	28%	57%
20-Year % Reduction	53%	53%	50%	71%
20-Year Tons of Reduction per Apartment	45	45	32	12

These results are based on long-run marginal emissions rates forecast for the state of Illinois by the National Renewable Energy Laboratory's (NREL) Cambium model. They are based on a scenario in which the state requires 95% emissions reduction from the grid by 2050, which is the best proxy – among the NREL scenarios one can select – for the expected emissions reductions under the 2021 Illinois Climate and Equitable Jobs Act (CEJA). Note that even under NREL's "mid-case" scenario which does not yet reflect the expected impacts of CEJA, electrification would reduce emissions by roughly 60% from water heating electrification and by about one-third for all other electrification scenarios over the next twenty years.

Chapter 2 Background

This chapter provides an overview of Peoples Gas residential customers. It also provides brief descriptions of the electrification technologies considered in the analysis. Detailed assumptions on the costs and performance for these technologies can be found in Chapter 3.

Residential Building Types and Gas Consumption by End Use

As Table 6 shows, a 2016 study of energy efficiency potential in its service territory estimated that Peoples Gas had a little less than 1.2 million residential housing units that used their gas for space heating in 2016.[7] Because our focus is on the economics of electrification for households paying residential electric and gas rates, we address only single-family and individually metered multi-family buildings. Approximately 53% of housing units served by Peoples Gas fall into one of those two categories (29% single-family homes and 24% individually metered multi-family apartments. Those two groups also represent a little more than 60% of the total residential gas sold by Peoples Gas. About 20% of the single-family households and nearly one-third of the individually metered multi-family households are low income.

Table 6: Peoples Gas Residential Gas Heating Customers[8]

	Total				Heating		Water Heating		Cooking		Drying	
	Premises	Units per Premise	Total Housing Units	Avg Therms	% with end use	Avg Therms	% with end use	Avg Therms	% with end use	Avg Therms	% with end use	Avg Therms
Single Family												
Non-low income	268,040	1	268,040	1295	100%	1001	95%	230	93%	55	79%	23
Low income	64,510	1	64,510	1414	100%	1111	92%	248	97%	60	69%	25
Total SF heat customers	332,550		332,550	1318	100%	1022	94%	233	94%	56	77%	23
Multi-Family												
Individual-meter non-low income	192,100	1	192,100	676	100%	514	90%	136	100%	33	50%	14
Individual-meter low income	91,530	1	91,530	766	100%	557	87%	180	100%	43	46%	18
Master-meter small non-low income	45,100	3.5	157,850	541	100%	417	90%	109	87%	21	67%	11
Master-meter small low income	17,330	3.3	57,189	594	100%	476	91%	102	87%	20	78%	10
Master-meter med. non-low income	6,930	15.2	105,336	745	100%	590	93%	136	58%	31	76%	14
Master-meter med. low income	2,510	18.1	45,431	709	100%	519	92%	171	48%	39	48%	17
Master-meter large non-low income	1,580	88.6	139,988	998	100%	699	97%	235	64%	71	79%	24
Master-meter large low income	570	67.4	38,418	893	100%	736	97%	130	55%	39	77%	13
Total MF heat customers	357,650		827,842	730		549	92%	153	80%	36	64%	15
All Heat Customers	690,200		1,160,392	898		685	93%	176	84%	42	68%	18

[7] There were another 94,430 master-metered residential premises that did not use gas for space heating. Those non-heat customers account for roughly 1% of Peoples Gas' total residential gas sales.

[8] *Peoples Gas Light and Coke Energy Efficiency Potential Study*, Prepared by Seventhwave with assistance from The Blackstone Group, March 2016.

As Table 6 also shows, about three quarters of gas used in both single-family and individually metered multi-family housing is for space heating. Most of the rest – a little less than 20% on average – is used for water heating. While the vast majority of both single-family and individually metered multi-family apartments also use gas for cooking, that typically accounts for only about 5% of total gas consumption. About three-quarters of single-family homes and half of individually metered multi-family apartments also use gas for clothes drying. However, even among households that have them, gas dryers only account for about 2% of total gas consumption.

Electrification Technologies

Space Conditioning

There are a variety of electric heating options including electric resistance baseboards, electric resistance furnaces, air source heat pumps, and ground source heat pumps and ground water heat pumps. Electric resistance baseboard and furnaces use resistive electric coils to generate the heat distributed to the building. Electric resistance heat, whether baseboard or furnace, is essentially 100% efficient (excluding any distribution losses through ducts), meaning it converts one BTU of electricity input to the heating system into one BTU of heat output. Heat pumps do not directly generate heat. Instead, they extract heat from air or water and move it into the home. As a result, they tend to be much more efficient, typically providing two to four BTUs of heat for every BTU of electricity input (i.e., 200% to 400% efficient).

For this report we only analyzed the air source heat pumps since they are the most likely to be both applicable and cost-optimal in most homes. Further, for electrification analyses, we focus on centrally ducted models. About three-quarters of both single-family homes and individually-metered multi-family apartments in Peoples Gas' service territory currently have central force air heating systems for which such centrally-ducted heat pumps would be the ideal replacement.[9] Most of the rest use either steam or hydronic heating systems. Again, since this

[9] *Peoples Gas Light and Coke Energy Efficiency Potential Study*, Prepared by Seventhwave with assistance from The Blackstone Group, March 2016.

report focuses on the economics of electrification for households paying residential electric and gas rates, master-metered buildings were outside of scope. Electrification of steam and/or hydronic heating systems, particularly in master-metered buildings, will require different heat pump technology and should be the subject of a separate analysis in the future.

We also assumed that the heat pumps would be cold climate models. Cold climate models use advanced compressor systems to deliver heat even as the outdoor air temperature (from which the heat is being drawn) drops. We define a cold climate model as one that can produce its full nameplate capacity for heat, with a coefficient of performance (COP) of at least 1.80 (i.e., an efficiency of 180%) at temperatures as low as 5 degrees F. Leading cold climate models can produce at least some heat in heat pump mode at even lower temperatures – e.g., down to -10 or -15 F[10] and for some models even down to below -30 F.[11] However, both the amount of heat and the efficiency with which it is produced declines as the outdoor temperature declines.

To ensure that there would not be concerns about comfort, we further assumed that centrally-ducted heat pumps in single-family homes would have up to 15 kW of electric resistance coils in the air handler (less should be required in multi-family apartments) to serve as back-up for the relatively small number of hours of the winter when temperatures are so cold that the heat pump may not be able to fully meet the heating demand. For reference, only about 10% of the days each year have a low temperature below 5 degrees F in Chicago.[12]

Though we did not analyze ground source heat pumps, as broad scale adoption will likely be limited, they could be a good option in some cases.

Water Heating

Options for electric hot water include standard resistance and heat pump water heaters. A heat pump water heater takes heat from the indoor air where it is located and transfers it to the

[10] One example is Mitsubishi's Hyper-Heating INVERTER (H2i) technology. https://www.mitsubishicomfort.com/benefits/hyper-heating.
[11] https://www.geappliances.com/ductless/
[12] Weatherspark.com, based on 4 station reporting for January 1980 through December 2016.

water it is heating. This results in cooling the air in the space where the water heater is located, which can be a benefit in the summer, but adds a little to the heating load in the winter.

As with space conditioning, electric resistance water heaters directly transfer almost all the electric energy to heat and therefore they have efficiencies of close to 100% (the only losses are standby losses, with heat from water sitting in a tank gradually escaping). Heat pump water heaters, relying on electricity to power a compression and expansion cycle, can get two or more units of useful heat energy from each unit of electricity and therefore have efficiency ratings that are commonly in the range from 300% to 400%.[13] There are cost and efficiency trade-offs, as a heat pump water heater can be two to three times more expensive than an electric resistance water heater. Our analysis focuses on heat pump water heaters because of the efficiency benefits.

Cooking

Electrification for cooking can use either standard resistance coil cooktops or induction cooktops. Resistance coils transfer heat to a pot or pan through conduction and convection. Induction units use an electromagnetic field and induction to directly heat magnetic cookware. Essentially, induction cooking cuts out the intermediate steps of heating up a burner or oven and then transferring that heat to the pot.[14] As with the other applications there are cost, efficiency, and performance trade-offs. We only included induction cooktops primarily because of their cooking performance benefits. Though they are more expensive than resistance coil cooktops, induction cooktops can provide both greater heating control and faster heating times than gas cooktops. They also have modest efficiency benefits relative to resistance coil cooktops.

[13] Energy Information Administration – Technology Forecast Updates, April 2018 prepared by Navigant Consulting estimated that the typical uniform energy factor (UEF) rating for heat pump water heaters sold in 2020 would be 3.28. Nearly 90% of Energy Star rated models have UEF ratings between 3.4 and 4.0 (https://www.energystar.gov/productfinder/product/certified-water-heaters/results). However, a 2016 NREL study in Northeast found field performance to be about 15% lower than rated performance (Shapiro, Carl and Srikanth Puttagunta (NREL), Field Performance of Heat Pump Water Heaters in the Northeast, February 2016).
[14] Consumerreports.org: Pros and Cons of Induction Cooktops and Ranges.

Clothes Drying

Like the other applications, clothes dryers can use electric resistance or heat pumps to dry clothes. With heat pump dryers the moisture from the clothes condenses on the cold coil of the heat pump unit and is drained through a pipe. This eliminates the need for venting the dryer air to the outside as is typical with conventional units. This can improve building thermal shell performance and eliminates the need for make-up air for dryer venting. However, due to higher costs relative to the efficiency benefits they provide, we assumed that conventional electric dryers (rather than heat pump dryers) would be the dryer electrification technology of choice.

Chapter 3 Methodology and Key Assumptions

Scope of Study

In this study we analyze the cost and carbon dioxide emission impacts of electrification options at the household level at several different decision points:

- **New construction** – we assume all end uses are met with electricity.
- **Existing buildings, full electrification at the time of HVAC replacement** – purchase and installation of a heat pump, heat pump water heater, induction stove and electric dryer at the time an existing furnace and/or central A/C would have otherwise been replaced.
- **Existing buildings, space heating electrification at the time of HVAC replacement** – purchase and installation of a heat pump at the time an existing furnace and existing central A/C system would have otherwise been replaced (we assume the furnace and central A/C are replaced together).[15]
- **Existing buildings, water heating electrification at the time of domestic water heater (DHW) replacement** – purchase and installation of a heat pump water heater at the time the household would otherwise have been replacing a gas model.

The mix of electrification decision points and end uses addressed are summarized in Table 7.

Table 7: Electrification Decision Points

Vintage	Full or Partial Electrification	Decision Point	End Uses Addressed			
			Heating & Cooling	Hot Water	Drying	Cooking
New	Full	Design/Construction	X	X	X	X
Existing	Full	Time of Replacement - HVAC	X	X	X	X
Existing	Partial	Time of Replacement - HVAC	X			
Existing	Partial	Time of Replacement - DHW		X		

[15] This is a simplifying assumption. Furnaces and central air conditioners are sometimes, but not always replaced together. If they would not have been replaced together, the incremental 20-year capital cost of installing a heat pump at the time of replacement of just the furnace (or just the central air conditioner) would be slightly higher than assumed in this analysis.

One could also consider the cost-effectiveness of electrifying heating systems or water heating systems by replacing existing well-functioning gas furnaces or water heaters. This is sometimes called "early replacement". Generally-speaking, it will be more cost-effective to electrify at the time an existing piece of equipment would otherwise be replaced, so that the incremental capital cost is only the difference between a new electric piece of equipment and a new gas piece of equipment, rather than the full cost of the electric equipment. However, if efficiency improvements and/or price advantages of electricity are large enough, it can also be cost-effective to electrify through early replacement of gas equipment.

Our analysis focuses on the comparative costs and savings that a household making electrification decisions in 2023 would have over the subsequent twenty years. This includes differences in initial capital costs, any replacement costs that would be incurred during the 20-year analysis period (i.e., for equipment expected to last less than twenty years), and the ongoing variable and fixed costs for electric and/or gas utility services.

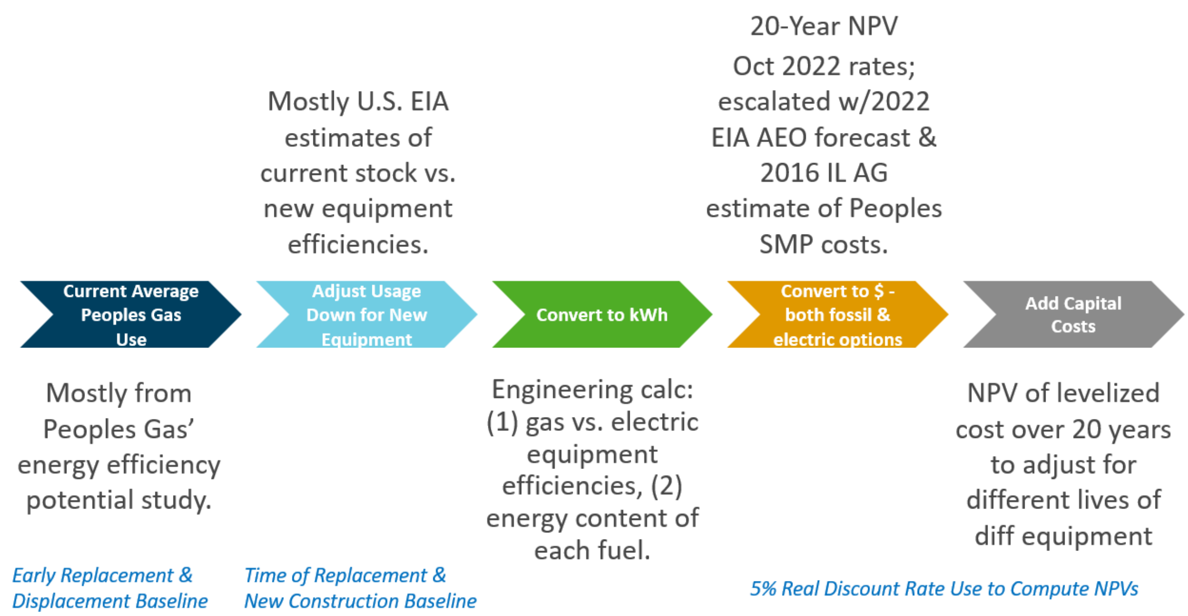
We suspect electrification would be more cost-effective under a societal economics assessment (rather than an assessment based on residential retail rates), because electric avoided costs are lower than retail rates (more so than gas), Illinois is summer-peaking so that winter avoided electric costs – when the increase in electric consumption from heating system conversions would occur – may be lower, and societal analyses would assign economic benefits to the reduction in greenhouse gas and other air pollutant emissions. However, we have not conducted such a societal assessment.

Overview of Approach

Figure 2 summarizes five major analytical steps for our analysis of the cost implications of electrification. We start with estimates of current average gas use for heating and other end uses in the average single-family home and the average multi-family apartment. This is sometimes called the average "stock consumption" or "stock efficiency" because it is a characterization of average energy use in the existing stock of homes. That average represents not only a mix of building sizes, styles and ages, but also of different ages and efficiencies of energy using equipment.

We then adjust the average existing gas consumption levels down to reflect improvements in efficiency that would result from replacing the average existing gas appliance with a new one. For example, if gas furnaces typically last 20 years, on average furnaces in existing homes will be about 10 years old and therefore, on average, less efficient than brand new ones since the efficiency of new appliances typically improves gradually over time. The magnitude of the downward adjustments for translating average stock consumption levels to average levels with standard new appliances is a function of assumed differences in the average stock efficiency and the average efficiency of new appliances. These adjustments are necessary to establish the baseline for gas usage for a time of replacement or new construction decision point.

Figure 2: Overview of Analytic Steps for Electrification Economics



We then estimate the magnitude of increased electricity consumption that would result from installation of new electric appliances (instead of new gas ones) based on engineering calculations using the energy content for each fuel and the annual operating efficiencies of electric and gas equipment for each end use.

The energy costs for households using the different fuel types are then compared, based on current rates and the projected changes to rates over the next twenty years. The analysis accounts for both the variable volumetric component and the fixed cost component of a household's energy bills. Households that electrify space heating but continue to use gas for cooking or other end uses are able to switch to a lower fixed monthly gas charge; those that fully electrify can eliminate their fixed monthly gas charge altogether. For any case in which space heating is electrified, our analysis also accounts for the benefits of being able to apply ComEd's electric heating rate, which is currently about 2.2 cents per kWh (including taxes) lower than it standard rate for single-family homes and 1.4 cents lower for multi-family apartments, to *all* electricity consumption in the home (not just to electricity consumption associated with space heating).[16]

Finally, the difference between capital costs for each piece of equipment are added. To account for varying lifetimes, we estimate the levelized annual cost for each piece of capital equipment, apply that annual cost to the full 20-year analysis period, and then compute the net present value (NPV) of the 20-year capital costs. This ensures an "apples to apples" comparison of the costs of equipment with different lives. For example, when comparing a gas furnace with an assumed average 20-year life to a heat pump with an average 16-year life one needs to account for costs to replace the heat pump within the twenty-year analysis period. The key assumptions and data sources for the economic analysis are detailed in the following section.

Key Assumptions for Economic Analysis

Current Average Peoples Gas' Single-Family Fossil Fuel Use

Estimates of average annual natural gas consumption by end use were drawn from the Peoples Gas' 2016 energy efficiency potential study.[17] For example, that study suggested that the average heating consumption for single-family homes with forced air heating systems (i.e., furnaces) was 985 therms. Note that this is a little lower than the average of 1022 therms across all single-family homes that was shown in Table 6 above. That is because the average heating consumption of forced air homes is lower than that of homes heated with either steam or

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[16] The electric heat rate also has slightly higher fixed monthly charges which we include in our analysis.
[17] See Appendix A of *Peoples Gas Light and Coke Energy Efficiency Potential Study*, Prepared by Seventhwave with assistance from The Blackstone Group, March 2016.

hydronic heating systems. The same study found that the average annual gas consumption in single-family homes for water heating, cooking and drying was 233 therms, 56 therms, and 23 therms respectively.

Current Average ComEd Single-Family Electricity Use

We estimate that the average existing central air conditioner in single-family homes (regardless of heating fuel) consumes 1550 kWh per year in ComEd's service territory. That is about 10% less than the 1720 kWh estimated in ComEd's 2013 efficiency potential study. That adjustment was made because the 2013 study estimate was based on data from just six years after a major increase in the federal minimum efficiency standard for central air conditioners (from SEER 10 to SEER 13 in 2006). We also estimate that the average gas dryer consumes 108 kWh per year for its electric motor[18] and that the average existing gas furnace fan consumes approximately 550 kWh per year.[19] However, we assume fan consumption levels for new furnaces will be only 300 to 325 kWh per year, as new furnaces are required to be equipped with more efficient fans.

Finally, we estimate average electricity consumption from end uses other than heating, cooling, water heating, cooking and drying – what we call miscellaneous electric consumption for this study – using U.S. Energy Information Administration's (EIA) 2015 Division 3 Residential Energy Consumption Survey (RECS) microdata. EIA RECS microdata suggest that the average non-electrically heated Illinois single-family home consumed 9112 kWh per year, but that nearly 1700 kWh of that total was for heating (e.g., fans), water heating, cooking and clothes drying. When we further subtracted our estimates of cooling energy consumption, the remaining consumption was 5870 kWh per year for ComEd. That estimate was particularly important for the analysis of space heating electrification because of the ability of households to switch to the Company's lower electric heating rate and realize bill savings on all electricity consumption – including miscellaneous uses.

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[18] This is an Efficiency Vermont estimate (https://www.efficiencyvermont.com/blog/how-to/how-much-electricity-does-your-home-use).

[19] This estimate is consistent with the 2015 EIA RECS estimate of 538 kWh for the East North Central Region.

Current Average Individually Metered Apartment Gas Use

Estimates of average energy consumption for heating, water heating, cooling and other end uses for individually metered multi-family apartments are from the same 2016 Peoples Gas energy efficiency potential study. For example, the potential study for North Shore Gas suggested gas heating consumption for individually metered apartments with furnaces was 549 therms per year. The average annual consumption for water heating, cooking and drying was 150 therms, 36 therms and 15 therms per year respectively.

Current Average Individually Metered Apartment Electricity Use

To simplify our analysis, we assumed that the average apartment cooling consumption is 50% less than the average single-family home, or 775 kWh per year. We further assumed that electricity consumption for dryer motors and furnace fans would be lower than in single-family homes in direct proportion to the amount by which gas consumption for drying and space heating was lower (i.e., 44% and 36% respectively) than in single-family homes.

As with the single-family analysis, we incorporated miscellaneous electricity consumption into the multi-family analysis using the U.S. Energy Information Administration's 2015 Residential Energy Consumption Survey microdata. Miscellaneous electricity consumption for multi-family households was significantly lower than in the single-family household analysis – 2771 kWh per year.

Adjustments to Baseline Consumption for Time of Purchase & New Construction

To create a baseline consumption estimate for both time of replacement and new construction decision points, we applied formulaic engineering calculations for most equipment based on assumed differences in efficiency for new equipment versus the (older) existing stock average. The basic formula for estimating the consumption for TOR and NC consumption levels is:

TOR/NC consumption = stock consumption * (stock eff. rating / new eff. rating)

Our primary source for new and stock equipment efficiency ratings was the Technology Forecast Update for Residential and Commercial Buildings prepared by Navigant Consulting for EIA in 2018.[20]

Electrification kWh Consumption Estimates

To estimate the annual kWh consumption for electrification measures we started by assuming the same energy output needed as for natural gas. The heating and cooling loads and the thermal shell efficiency of the building was therefore assumed to be static, while the fuel type and the efficiency of the systems providing the heating and cooling varied. We use engineering formulae to convert gas use to an equivalent kWh based on BTU content of different fuels and adjust these based on the efficiency ratings of gas and electric equipment. The formula is typically as follows:

kWh = therms * (100,000 BTU/therm) * (gas COP / electric COP) * (kWh/ 3413 BTU)

One notable exception to this formula is for heat pump water heaters. Because they remove heat and moisture from the air around them, heat pump water heaters located in conditioned spaces affect heating, cooling and dehumidification energy needs in a home. Based on formulas in version 11 of the Illinois utilities' Technical Reference Manual for estimating energy savings from efficiency measures,[21] we estimate these effects to be an extra 37 kWh needed in winter months and 144 less kWh needed summer months, for a net total annual decrease in consumption for space conditioning of 107 kWh for heat pump water heaters located in conditioned spaces.[22] We assumed 50% of HPWHs are located in conditioned space, resulting in a decrease – above water heating kWh consumption estimates that would result from the formula above – of 53 kWh per year.

[20] https://www.eia.gov/analysis/studies/buildings/equipcosts/pdf/appendix-a.pdf

[21] https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010123_v11.0_Vol_3_Res_09222022_FINAL.pdf

[22] The reason the increase in kWh consumption in winter is so much smaller than the decrease in the summer is that dehumidification benefits offset most of the heating penalty in winter; they also add to the cooling benefits in summer.

In most cases, we based electric COPs (i.e., efficiencies) on the same 2018 EIA Technology Forecast used for gas equipment efficiency estimates for new equipment sales.[23] However, there are a couple of notable exceptions. First, for heat pump water heaters, we adjusted rated energy factors down by 15% to reflect the results of field studies suggesting their actual performance in colder climates is not quite as good as their rated efficiencies would suggest.[24]

Second, for cold climate air source heat pumps we based COP/efficiency estimates on cold climate heat pump performance characteristics rather than on the average heat pump sold nationally, as cold climate models would be most appropriate for Chicago's climate. Specifically, we assumed an average annual heating season COP, including a small amount of electric resistance back-up heat, of 2.60 in ComEd's territory. That is based in part on results from ComEd's recent low-income multi-family cold climate heat pump retrofit pilot program, which found an average COP for single head ductless mini splits of 2.63.[25] It is also consistent with preliminary testing of cold climate heat pump performance, for eight different North American climate zones, according to a new protocol whose development is being led by the Canadian Standards Association. Chicago is right in the middle of what is called the "cold-humid" climate zone. The average COP for most of the first dozen cold climate heat pumps tested according to this protocol as in the 2.5 to 2.6 range.[26]

Cold climate air source heat pumps reduce electricity for cooling, as they typically have a higher cooling efficiency (SEER rating) than central air conditioners. Existing central ACs are assumed to have a SEER rating of 13.0. That is consistent with trends in improving stock

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[23] EIA Technology Forecast Updates, prepared by Navigant Consulting, April 2018 (https://www.eia.gov/analysis/studies/buildings/equipcosts/pdf/appendix-a.pdf).

[24] Shapiro, Carl and Srikanth Puttagunta, Field Performance of Heat Pump Water Heaters in the Northeast, prepared for the National Renewable Energy Laboratory on behalf of the U.S. Department of Energy's Building America Progarm, February 2016 (https://www.nrel.gov/docs/fy16osti/64904.pdf).

[25] CMC Energy Services, Ductless Heat Pump Final Report, prepared for ComEd Energy Efficiency Program Emerging Technology, May 7, 2020. Note that the study found multi-head ductless heat pumps to have a much lower seasonal average COP of 1.47. That is likely a function of challenges associated with multiple indoor heads drawing from a single outdoor compressor. Single head ductless systems are much more analogous to centrally-ducted systems which also have one outdoor compressor connected to one indoor air handler.

[26] See slides 9 and 27 of Harley, Bruce and Christopher Dymond, EXP-07 Preliminary Results, presentation to the Northwest Energy Efficiency Alliance, November 26, 2019 (https://conduitnw.org/Pages/File.aspx?rid=4967).

efficiency of SEER 11.4 in 2009 and SEER 12.5 in 2015, as documented by EIA.[27] We assumed new central air conditioners would have an average SEER rating of 14, consistent with minimum federal efficiency standards going into effect in 2023. The efficiency of a centrally ducted cold climate heat pump unit is assumed to be SEER 18, resulting in savings for time of replacement units of roughly 320 kWh in the Chicago area.

Table 8 and Table 9 summarize the single-family and individually metered multi-family energy consumption and efficiency assumptions in our electrification analyses. Though not shown in the table, gas furnaces and gas dryers also consume modest amounts of electricity.

Table 8: Single-Family Energy Consumption and Efficiency Assumptions[28]

End Use	Units	Existing Stock	Time of Replace	New Home	Efficiency Assumed Stock - TOR/NC
Not Electrified					
Heating	therms	985	910	910	0.85 to 0.92
Cooling	kWh	1550	1439	1439	13.0 to 14.0
Hot Water	therms	233	222	222	0.60 to 0.63
Cooking	therms	56	50	50	40% to 45%
Drying	therms	23	23	23	3.25 to 3.32
Electrified					
Heating	kWh	9434			2.6
Cooling	kWh	1119			18.0
Hot Water	kWh	1411			2.8
Cooking	kWh	452			n.a.
Drying	kWh	714			3.74

[27] EIA Technology Forecast Updates, prepared by Navigant Consulting, April 2018, Residential Central Air Conditioners.

[28] The values in this table are for just those end uses that could potentially be electrified (i.e., heating, water heating, cooking and drying) or whose consumption would likely be affected by electrification (i.e., cooling, because cold climate heat pumps are more efficient than central air conditioners). As discussed above, there is also substantial electricity consumption associated with other end uses, but the level of consumption associated with those other end uses is assumed to not change as a result of any electrification. However, the household costs of such consumption would to go down if heating is electrified because homeowners and tenants can get on ComEd's lower electric heating rate.

Table 9: Individually Metered Apartment Energy Consumption and Efficiency Assumptions

End Use	Units	Existing Stock	Time of Replace	New Home	Efficiency Assumed Stock - TOR/NC
Not Electrified					
Heating	therms	549	507	507	0.85 to 0.92
Cooling	kWh	775	720	720	13.0 to 14.0
Hot Water	therms	150	143	143	0.60 to 0.63
Cooking	therms	36	32	32	40% to 45%
Drying	therms	15	15	15	3.25 to 3.32
Electrified					
Heating	kWh	5254			2.6
Cooling	kWh	560			18.0
Hot Water	kWh	888			2.8
Cooking	kWh	291			n.a.
Drying	kWh	458			3.74

Estimating Change in Energy Costs from Electrification

Once the annual energy consumption for new natural gas systems and their electric replacement options are estimated we assess the operating costs for each alternative over the next twenty years. We started with gas and electric utility rates in October 2022. All of the line items on utility bills – including taxes, efficiency program charges, environmental charges, and Peoples' Qualified Infrastructure Plant (QIP) charges – were allocated to variable and fixed charges.

Table 10 summarizes the starting variable and fixed values for single-family homes. Note that though ComEd's electric heat rate is lower per kWh, the fixed monthly charge is slightly higher than the non-electric heat rate. Peoples Gas has the same variable charge for heating and non-heating customers, but a considerably lower fixed charge for non-heating customers.

Note also that though Peoples Gas rates are the same for single-family and multi-family customers, ComEd's are slightly different. Most notably, ComEd's fixed monthly charges for multi-family customers than for are about 20% lower than for single-family customers. Also, the difference in variable charges per kWh between electric heat and non-electric heat customers is smaller for multi-family customers (about 1.4 cents per kWh including the effects of taxes) than for single-family customers (about 2.2 cents per kWh). That is important because one of the benefits of heating electrification is that households will not only be able to apply ComEd's lower electric heat rate to their space heating electricity consumption but also to all other electricity consumption. The benefit of having the lower variable heating rate applied to miscellaneous electric uses is worth an average of almost $1,500 (in net present value terms) over the next twenty years for single-family households (in net present value terms) and about $440 for individually metered multi-family households.

Table 10: Current Single-Family Utility Rates

	2022 Variable Costs		2022 Fixed Costs	
Utility	**$/Therm**	**$/kWh**	**Monthly**	**Annual**
Peoples Gas Heat	$1.65	n.a.	$51	$606
Peoples Gas Non-Heat	$1.65	n.a.	$26	$316
ComEd Electric Electric Heat	n.a.	$0.093	$15	$185
ComEd Electric Non-Electric Heat	n.a.	$0.115	$14	$167

Over the coming 20 years fuel costs are expected to change. For the variable portion of Peoples Gas' bills, we assumed costs per therm will decline in real (i.e., inflation-adjusted) terms by 17.5% between 2022 and 2025 and then begin to gradually increase so that they reach current prices in 2035 and eventually peak at $1.73 in 2040. These assumptions are based on regional forecasts of how gas utility costs are generally expected to change plus an additional adjustment to account for Peoples Gas' very large, planned capital investment to replace pipes as part of what it calls its "safety modernization plan" (SMP).

The U.S. Energy Information Administration's (EIA's) 2022 Annual Energy Outlook (AEO) forecast of real (inflation-adjusted) gas utility cost changes for the East North Central Region (which includes Illinois) is the foundation of our estimates of future gas price changes.[29] Note that current prices in futures markets for gas suggest that prices will be a little higher over the next five years than forecast by EIA. However, we decided to use EIA's forecast so that the source for future price changes is consistent for both gas and electricity. To the extent that future

[29] Energy Information Administration, Annual Energy Outlook, 2020, Energy Prices Residential Reference case, East North Central Region.

gas price increases are more in line with current futures markets than EIA's 2022 AEO forecast, electrification will likely be more cost-effective than our analysis suggests.[30]

To address the impacts of Peoples Gas' SMP capital investments, we started with an estimate of the increased annual impact on the average residential heating customer's gas bill that was developed by an expert witness for the Illinois Attorney General (AG) in 2016. Given how the project has evolved in recent years, we focused on the AG witness' estimate of bill impacts in a scenario in which the SMP deployment was not completed until 2040.[31] We allocate the AG witness' estimates of post-2022 annual increases to the fixed and variable portions of the bill based on current (2022) average allocations of Qualified Infrastructure Project (QIP) costs to the fixed and variable portions of single-family and multi-family gas bills. For single-family homes, about half of the QIP costs are currently allocated to fixed charges and half to variable charges; for individually-metered apartments about two-thirds of QIP charges are allocated to fixed charges and one-third to variable charges.[32] We also scale the AG witness' estimates of post-2022 annual increases up for single-family customers and down for individually-metered multi-family apartments to reflect differences between the AG witness' estimate of the average heating customer's (single-family and multi-family combined) gas usage and our higher estimates for single-family homes and lower estimates for multi-family homes.

We start with the same 2022 EIA AEO forecast to adjust future electricity prices. The 2022 AEO forecasts an average annual real decrease in electricity prices of 0.39% between 2022 and 2042. We further adjust electricity prices up beginning in 2028 – beyond the annual changes

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[30] Note that gas prices will also have some effect on future electricity prices.

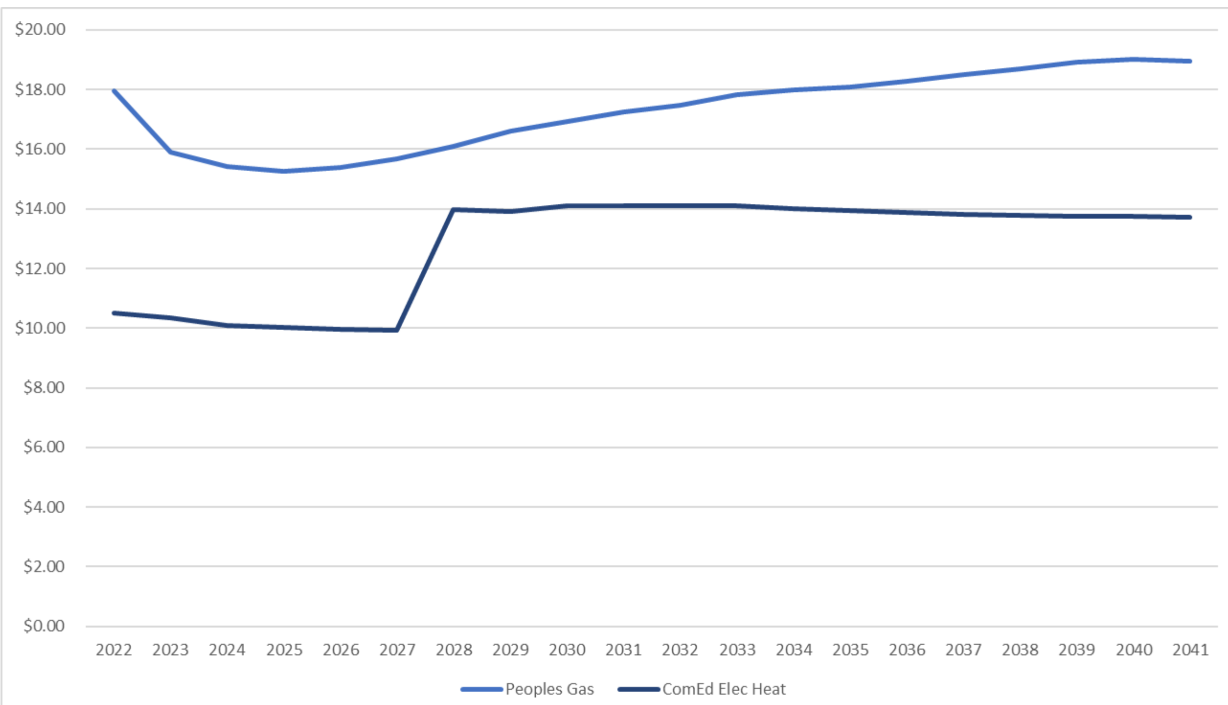
[31] Revised Direct Testimony of Sebastian Coppola on behalf of the People of the State of Illinois (AG Exhibit 2.0R), filed in Docket No. 16-0376, November 2, 2016; Coppola workpaper #9.

[32] QIP charges are percentage multipliers applied to fixed monthly charges and a range of variable charges including the distribution charge, storage service charge, volume balancing charge, invested capital tax adjustment and other cost adjustments. Peoples Gas' fixed monthly charge is the same for multi-family apartments as for single-family homes. Thus, in absolute dollars, the QIP allocation to fixed charges is the same for both building types. However, because single-family homes typically consume more gas than multi-family apartments, the average annual dollars of QIP allocations to variable charges are greater for single-family homes than for multi-family apartments. That is why the portion of QIP charges that are variable is greater for single-family homes.

forecast by in AEO – to account for the expected sunsetting of the carbon-free energy resource adjustment. That increase is about 3.6 cents per kWh.

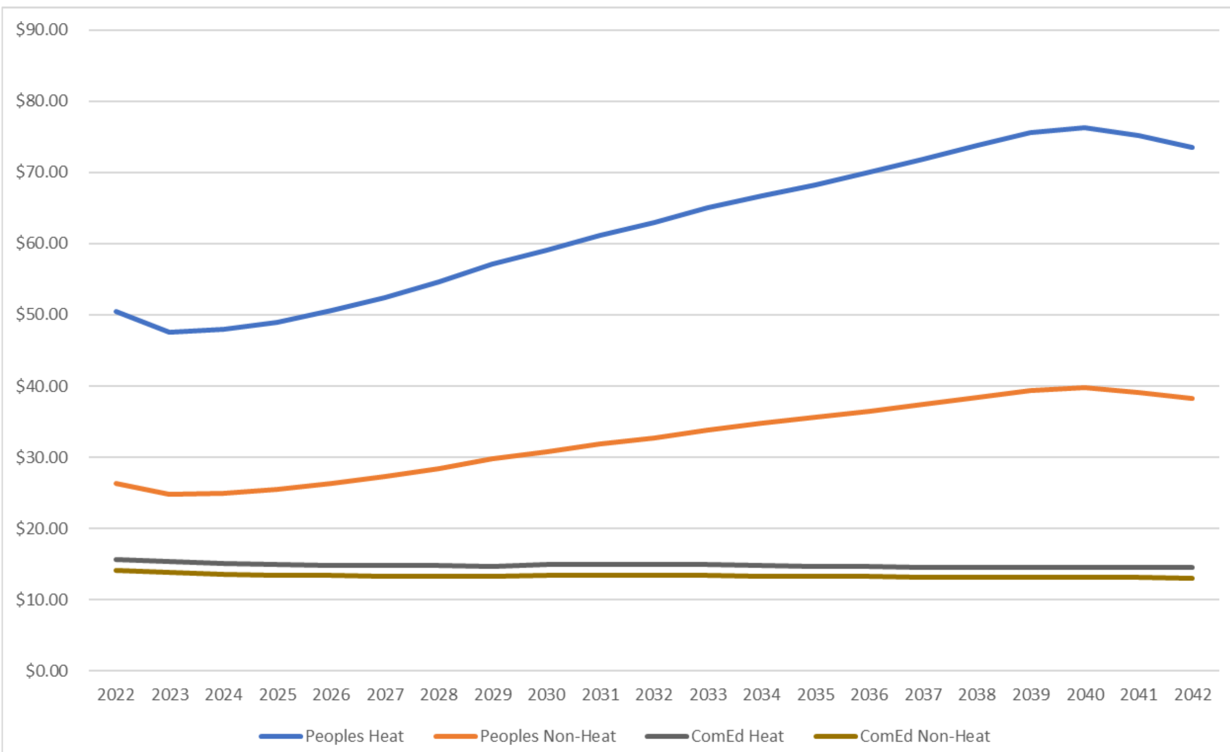
Figure 3 illustrates forward-looking variable costs per MMBtu of *heating output* by fuel type, which is the price per MMBtu of heating input divided by the average efficiency of the heating system. This is very different than the cost per MMBtu of *energy input*. The variable cost of gas per unit of *energy input* is considerably lower than the variable cost of electricity per unit of *energy input*. However, because the efficiency of electric heat pumps (260% assumed in our analysis) is so much higher than the efficiency of gas furnaces (92%), electricity ends up being less expensive per unit of *heating output*.

Figure 3: Variable Single-Family Gas and Electric Energy Costs per Unit of Heat (2022 $)



Our estimates of changes to fixed charges on gas and electric bills were developed using the same two inputs used to forecast changes to variable charges – EIA's 2022 AEO forecast changes in utility costs plus an adjustment for fixed charge portion of Peoples Gas' future SMP costs. The single-family results are presented in Figure 4. The multi-family values are the same for Peoples Gas, but about 20% lower for ComEd. Note that Peoples has a higher fixed monthly charge for electric heat customers than for non-electric heat customers. The difference between those two fixed charges is a benefit that would be realized by households which electrify space heating but continue to use gas for other end uses (e.g., water heating, cooking and/or drying). Households which fully electrify can eliminate gas fixed charges altogether. Again, these fixed charges include fixed monthly charges, taxes applied to the fixed monthly charges and – for Peoples Gas – the application of QIP percentages to fixed monthly charges.

Figure 4: Single-Family Fix Monthly Gas and Electric Charges (2022 $)



Finally, we use a real discount rate of 5% to compute a net present value (NPV) of the 20-year stream of energy costs under both the electrification scenario and the baseline scenario of continuing to use gas.[33]

[33] Discount rates represent an assumed time preference for money. People generally prefer having a dollar today over having a dollar tomorrow. That is only partly because inflation will reduce the future buying power of a dollar. Even if there was no inflation, people would prefer having money today rather than tomorrow. The higher the discount rate, the higher the implied preference for money this year instead of next year or any subsequent

Estimating Capital Costs of Electrification

Table 11 summarizes our capital cost estimates for both single-family homes and multi-family apartments. For gas furnaces, central air conditioners, gas water heaters, gas dryers, heat pump water heaters and electric dryers we based capital cost estimates on forecasts developed by Navigant Consulting for EIA's 2020 Annual Energy Outlook.[34] For multi-family furnaces and central air conditioners we adjusted the EIA estimates to reflect lower expected costs for smaller equipment based on reviews of on-line prices from major retailers such as Lowe's and Home Depot as well as the on-line cost estimator at www.homewyse.com.

Because the Navigant forecast did not specifically address cold climate heat pumps, which are a relatively new technology, we based heat pump cost estimates for both single-family and multi-family sized systems on information provided by leading manufacturers. Note that we included the cost of back-up electric resistance coils in the air handler. Note also that, for the time of HVAC replacement decision point, the cost of a high-performance electric heat pump, which provides both heating and cooling, is compared to the combined replacement cost for an upgraded furnace with 92% efficiency and a 14 SEER Central AC.

For stoves, we estimated the cost of both natural gas products and electric induction products based on on-line prices from major retailers such as Lowe's and Home Depot. Single-family new construction gas connection costs are based on an estimate from DTE, one of the two large gas utilities in Michigan.[35] Based on anecdotal information, we have assumed that the cost per new multi-family apartment would be half as large as for single-family homes.

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year. *Real* discount rates represent the magnitude of that "beyond inflation" time preference. *Nominal* discount rates reflect the combined effects of time preferences and inflation. For example, a 5% real discount rate is the same as an 8.2% nominal discount rate if long-term inflation is projected to average 3% per year. We use a real discount rate in our analyses because we express all costs in 2022 dollars (i.e., costs already adjusted for any future inflationary impacts).

[34] EIA Technology Forecast Updates, prepared by Navigant Consulting, April 2018 (https://www.eia.gov/analysis/studies/buildings/equipcosts/pdf/appendix-a.pdf).

[35] DTE Energy. (March 15, 2022). Residential Heat Pump Breakeven Analysis. Prepared for the Michigan Energy Waste Reduction (EWR) Collaborative by Guidehouse, Inc. P. 15. https://www.michigan.gov/mpsc/-/media/Project/Websites/mpsc/workgroups/EWR_Collaborative/2022/DTE-HP-Breakeven-Analysis.pdf?rev=36d0a18da7cd4b93833f76629655f42b&hash=D5A55F0F12D0C331AFDFECA41798909B.

Table 11: Initial Equipment Costs (2022 $)

		Continued Use of Gas	Electrification	Difference
Single Family HVAC				
	92% Gas Furnace	$3,341		
	14 SEER Central A/C (3-ton)	$4,418		
	2.6 heating COP, SEER 18 Centrally-Ducted Cold Climate HP (3-ton)		$9,605	
	Total	$7,758	$9,605	$1,847
Multi-Family HVAC				
	92% Gas Furnace	$2,739		
	14 SEER Central A/C (1.5-ton)	$3,623		
	2.6 heating COP, SEER 18 Centrally-Ducted Cold Climate HP (1.5-ton)		$6,436	
	Total	$6,362	$6,436	$74
DHW				
	0.63 EF Gas Water Heater	$1,694		
	3.28 EF Heat Pump Water Heater		$2,511	$817
Dryers				
	Gas	$799		
	Electric		$654	($145)
Oven/Cooktop				
	Gas	$798		
	Electric (Induction)		$1,098	$300
Other				
	Gas Connection Cost (Single-Family New Construction)	$6,000		n.a.
	Gas Connection Cost (Multi-Family New Construction)	$3,000		n.a.

All referenced costs were increased to reflect changes in the consumer price index (i.e., to address inflation) since they were developed.

Accounting for Future Capital Costs

Our analyses of electrification cover a 20-year period. Because some equipment – both gas and electric – does not last 20 years, we need to account for some future capital costs during the 20-year analysis period. For example, while a gas furnace is assumed to last 20 years, a central A/C is only assumed to last 18 years and a heat pump is only assumed to last 16 years.

To account for these varying equipment lifetimes, we annualized capital costs of equipment over the lifetime of each piece of equipment. Annualization is like turning a purchase price for a home into an annual mortgage payment. For example, at a 5% real discount rate, the annualized capital cost of a $9,605 single-family heat pump is $844 per year and the annualized capital cost of a $3,341 single-family gas furnace is $255 per year. Those values are assumed to be incurred in each year of the 20-year analysis. We then calculated the discounted net present value (NPV) of those 20-year streams of annualized capital costs. In the case of a centrally-ducted heat pump, that translates to a 20-year NPV, using the same 5% real discount rate, of $11,045. That is higher than the $9,605 initial cost because it captures part of the cost of having to replace the heat pump four years before the end of the 20-year analysis period. For the gas furnace, the 20-Year NPV of annualized costs is $3,341 – exactly equal to the initial capital cost because the furnace life of 20 years is exactly equal to our analysis period. In short, the annualization of capital costs enables an "apples to apples" comparison of equipment with different lives.

Our assumptions regarding equipment lifetimes are presented in Table 12. In most cases they are based on assumptions in the Illinois utilities' Technical Reference Manual (TRM) for assessing impacts of energy efficiency measures. Because the Illinois TRM does not include assumptions for stoves, our estimate for those technologies is based on Navigant's 2018 Technology Forecast for EIA.

Table 12: Equipment Lifetimes[36]

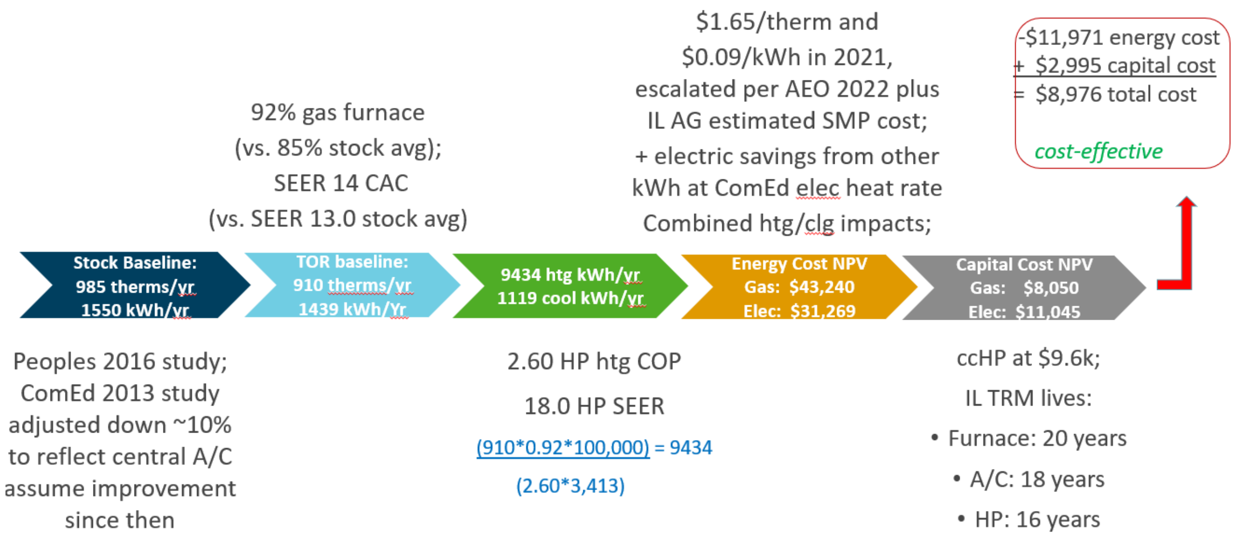
HVAC	Measure Life (Years)
92% Gas Furnace	20
14 SEER Central A/C	18
2.6 heating COP, SEER 18 Centrally-Ducted Cold Climate HP	16
DHW	
0.63 EF Gas Water Heater	13
3.28 EF Heat Pump Water Heater	15
Dryers	
Gas	16
Electric	16
Oven/Cooktop	
Gas	12
Electric (Induction)	12

[36] Equipment lifetimes from the Illinois TRM, version 8.0.

Putting it All Together

The preceding analytic steps are illustrated in Figure 5 using a time of replacement for a single-family HVAC system as an example. In this case, the energy operating costs over the 20-year analysis period are $11,971 lower after electrification but the capital costs for a high efficiency cold climate heat pump are $2,995 greater over the twenty-year analysis period than the gas replacement alternative, resulting in a net 20-year cost savings of $8,976.

Figure 5: Single-Family HVAC Time of Replacement Example Analysis



Key Assumptions for Emissions Analysis

Differences between emissions from electrified households and those continuing to use natural gas will depend upon how electricity is generated. For this report we relied on long-run marginal emissions rates forecast for Illinois by the National Renewable Energy Laboratory's Cambium model.[37] They are based on a scenario in which a 95% emissions reduction from the grid is required by 2050, which is the best proxy – among the NREL scenarios one can select – for the expected impacts of the 2021 Illinois Climate and Equitable Jobs Act (CEJA).[38]

[37] https://scenarioviewer.nrel.gov/?project=a3e2f719-dd5a-4c3e-9bbf-f24fef563f45&mode=view&layout=Default.

[38] NREL updates the Cambium model annually. However, the 2022 update, which should include adjustments to account for CEJA impacts in NREL's "mid-case" scenario, is not yet available.

Chapter 4 Results

Impacts of Electrification on Residential Energy Costs

The impacts of electrification on household costs are summarized in Table 13 (single-family) and Table 14 (multi-family). The first section of each table shows the amount by which total energy costs – including both (A) capital costs for heating, water heating and other end use equipment; and (B) energy bills over the next twenty years – are reduced. The values are expressed in net present value (NPV) terms. The second section shows just the amount by which energy bills are lowered in just the first year after electrification takes place.

Table 13: Single-Family Cost Savings from Electrification (2022 $)

	All Electric New Construction	Existing Home Full Electrification	Existing Home Heating Electrification	Existing Home Water Heat Electrification
20-Year NPVs of Total Cost Savings from Electrification (Capital + Energy)				
Without Federal Incentives	$20,192	$13,351	$8,976	$1,361
With IRA Low Income Rebate	$31,436	$24,594	$16,976	$3,111
With IRA Moderate Income Rebate	$25,814	$18,973	$12,976	$2,236
With IRA Tax Credits	$22,946	$16,104	$10,976	$2,115
1st Year Energy Bill Savings from Electrification				
	$1,445	$1,445	$941	$165

Table 14: Multi-Family Cost Savings from Electrification (2022 $)

	All Electric New Construction	Existing Home Full Electrification	Existing Home Heating Electrification	Existing Home Water Heat Electrification
20-Year NPVs of Total Cost Savings from Electrification (Capital + Energy)				
Without Federal Incentives	$15,299	$10,889	$7,373	$711
With IRA Low Income Rebate	$24,978	$20,569	$13,809	$2,461
With IRA Moderate Income Rebate	$20,138	$15,729	$10,591	$1,586
With IRA Tax Credits	$17,983	$13,574	$9,304	$1,464
1st Year Energy Bill Savings from Electrification				
	$1,036	$1,036	$605	$114

As both tables show, residential electrification in Peoples Gas territory will save a lot of money over our twenty-year analysis period. That is the case even without any federal incentives (the first row). When federal Inflation Reduction Act (IRA) rebates and/or tax credits are applied, even greater cost-savings are realized. The impact of the IRA incentives is greatest for low-income households – those whose incomes are at or below 80% of area median income (AMI) – because the IRA incentives are largest for such households (e.g., up to $8,000 for a heat pump and up to $1,750 for a heat pump water heater). For a household of four people, 80% of AMI in Cook County is currently $83,350 in annual income.[39] IRA rebates for moderate income households – those with incomes between 80% and 150% of area median income – are expected to be half as great as those for low income, which is still quite substantial. For a household of four people, 150% of AMI in Cook County is probably on the order of $155,000 in annual income.[40] The IRA's 30% tax credit is available to any household that has a large enough tax liability to take advantage of them. The maximum annual tax credit for heat pumps and or heat pump water heaters is $2,000. Note that some homeowners could potentially be eligible for both tax credits and rebates (mostly likely only moderate-income rebates). We have not separately shown the impacts for such cases.

As the last row in each of the tables above also shows, households which electrify will see reductions in their energy bills in the very first year. In other words, the cost-effectiveness of electrification is not predicated on assumptions about gas prices rising faster than electricity prices.

While all forms of electrification will lower costs, space heating electrification (20-year savings ranging from about $7,000 to nearly $17,000, depending on building type and IRA incentive eligibility) will provide greater savings than water heating electrification (20-year savings ranging from about $700 to over $3,000). There are several reasons for this. First, after accounting for differences in the efficiency of gas and electric equipment, ComEd's electric rates are lower than Peoples Gas' gas rates. That is true both today and in the future. It is primarily a function of substantial regional and national increases in the wholesale cost of gas and the significant additional costs that households are now paying through the Qualified Infrastructure Plant (QIP) surcharge on their Peoples Gas bills for the utility's investments in replacing the

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[39] https://www.chicago.gov/city/en/depts/doh/provdrs/renters/svcs/ami_chart.html

[40] Ibid. 120% of AMI is an annual income of about $125,000; 140% of AMI is about $146,000.

pipes it uses to bring gas to homes and businesses. Since space heating requires more energy than water heating, the total annual bill savings are greater for space heating. Second, electrification allows households to switch to ComEd's lower cost electric heat rate which saves households money not only on their heating bill but also on all other uses of electricity (e.g., lighting, refrigeration, computers, TVs, etc.). Third, space heating electrification allows households to pay lower fixed monthly charges for the gas they may still use for cooking, drying, water heating or other uses. This benefit is particularly important because the fixed monthly cost on Peoples Gas bills has also grown substantially as a result of increasing QIP surcharges. Fourth, cold climate heat pumps are significantly more efficient in cooling mode than the central air conditioners that they replace, providing additional cooling cost savings.

It should also be noted that full electrification of existing homes – in which all gas uses are converted to electricity – produces between $3,500 and $7,600 more cost savings than just space heating electrification. This is mainly because full electrification allows households to eliminate *all* fixed monthly charges for gas. Although there are additional capital costs associated with full electrification (e.g., replacing gas stoves and dryers), the value of avoiding all fixed monthly charges on gas bills significantly outweighs those added capital costs.

All electric new construction provides even greater cost savings than full electrification of existing homes. Part of the reason is that in new construction one only needs to incur the incremental cost of upgrading from a gas stove to an electric one (rather than the full cost of replacing a gas stove in an existing home). More important is the ability to avoid substantial costs associated with both running gas pipes within the home and connecting to the gas utility's distribution system.

Caveats and Sensitivities of Estimated Impacts on Costs

As the discussion in Chapter 3 makes clear, numerous assumptions must be made to perform a thorough assessment of the cost implications of electrification. Below we flag several key assumptions and explain the degree to which changes in those assumptions would affect our conclusions.

Results for the Average Home

Our analysis is based on the average single-family home and the average multi-family apartment served by Peoples Gas. Some homes will consume more energy for heating or other energy needs than others; some will consume less. The magnitude of reductions in costs from electrification will be affected by the amount of energy a household consumes. We conducted sensitivity analyses for both homes that consume half as much and homes that consume twice as much as the average home for space heating. Electrification remained very cost-effective in both cases.

No Building Efficiency Improvements Assumed

The corollary to the point above is that our analysis did not assume any efficiency investments were made in homes. To the extent that there are cost-effective opportunities to reduce air leakage, increase insulation and/or make other efficiency improvements to a home, such investments will lower energy bills while also providing comfort and other non-energy benefits. Of course, this would be true whether a gas-heated home continued to burn gas or whether it is electrified. However, if efficiency upgrades are made at the same time as electrification, they could enable a smaller new heat pump to be installed, modestly lowering the initial incremental capital cost required for electrification.

Assumption that No Electric Panel Upgrades are Necessary

The results we have presented are for homes for which no electric panel upgrades are necessary to enable electrification. However, even if electric panel upgrades are needed, that would not change our conclusions about the typical cost-effectiveness of electrification. For example, our estimate of $13,351 in total cost savings over 20 years from fully electrifying a single-family home (excluding IRA incentives) would decline to a still very substantial $10,851 if the electric panel upgrade cost was $2,500. Moreover, the federal IRA rebates will cover all of the cost of such electric panel upgrades for low-income households and half of such costs for moderate income households.

Assumption that Furnace and Central Air Conditioner Replaced Together

As explained in Chapter 3, our analysis of electrification for both the HVAC time-of-replacement scenario and the full electrification scenario for existing homes assumed that the home's existing gas furnace and existing central air conditioner would both have otherwise been replaced. While many households replace both pieces of equipment at the same time, many replace just one and leave the other until replacement is more urgent. Needless to say, the cost savings we found for electrification of space heating would be lower if the household was planning to replace only its furnace or only its central air conditioner rather than both pieces of equipment. However, it would still be very cost-effective to electrify. For example, if only the furnace would otherwise have been replaced, the total cost savings over twenty years from full electrification of a single-family home would still be $10,665 (without IRA rebates), or about $2,400 lower than estimated in our base analysis.[41]

Excludes Benefits of ComEd and/or City of Chicago Financial Incentives.

Our analysis does not account for any additional cost reductions that households may realize from rebates for electrification measures beyond those provided by the federal IRA. Any ComEd or City of Chicago rebates will increase total cost savings.

Potentially Conservative Assumptions about Future Gas Prices.

As discussed in Chapter 3, our estimates of the rate at which gas and electricity prices will increase in the future are based primarily on the U.S. Energy Information Administration's (EIA's) 2022 Annual Energy Outlook (AEO) for the East North Central region (which includes Illinois).[42] Current prices in futures markets for gas suggest that prices will be a little higher over

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[41] As explained in Chapter 3, we assume that the average new single-family central air conditioner costs $4418. While that is the initial (first year) savings from not having to replace a central air conditioner, it is not the 20-year savings. For cases in which a new central air conditioners is assumed to not be replaced at the time the furnace is replaced, we assume that the central air conditioners is (on average) half way through its 18-year life and would therefore have had to be replaced in nine years. This sensitivity analysis accounts for the discounted impact of that deferred replacement cost.

[42] The only adjustments we made to the EIA 2022 AEO escalation rates was to account for the significant additional capital expenditures for gas pipe replacements forecast for Peoples Gas' "Safety Modernization Program" and the forecast sunsetting of ComEd's carbon-free energy resource adjustment after 2027.

the next five years than forecast by EIA. We decided to use EIA's forecast so that the source we reference for future price changes is consistent for both gas and electricity. To the extent that future gas price increases are more in line with current futures markets than EIA's 2022 AEO forecast, electrification will likely be more cost-effective than our analysis suggests.[43]

5% Real Discount Rate Used for NPV Calculations

Sensitivity analyses suggest that electrification is cost-effective under any reasonable assumption about the real discount rate. For example, the $13,351 total cost savings for full electrification of existing homes – without any federal incentives – increases to about $21,000 with a 1% real discount rate (slightly higher than the societal discount rate ComEd, Peoples Gas and other Illinois utilities use to assess the cost-effectiveness of their efficiency programs) and declines to a little under $8,000 with a 10% real discount rate.

Emissions Impacts of Electrification

As Table 15 and Table 16 show, electrification will produce substantial CO_2 emissions reductions for all of the different single-family and multi-family decision points that we have analyzed. As one would expect, the tons of emission reductions (last row of each table) are greatest for full electrification, almost as large for just space heating electrification because space heating accounts for the lion's share of gas use in most homes, and smallest for water heating. However, the percent reductions are largest for water heating because the efficiency difference between gas and electric water heating equipment (63% for gas, 280% for electric) is bigger than for space heating (92% for gas, 260% for electric). Note also that these are just direct carbon emission reductions from combustion. We have not estimated the lifecycle emission reductions associated with fossil gas production and transportation as well as combustion.

[43] Note that gas prices will also have some effect on future electricity prices.

Table 15: Single-Family CO_2 Emissions Reductions Across End Uses Electrified

	All Electric New Construction	Existing Home Full Electrification	Existing Home Heating Electrification	Existing Home Water Heat Electrification
1st Year % Reduction	30%	30%	28%	56%
20-Year % Reduction	52%	52%	50%	71%
20-Year Tons of Reduction per Home	78	78	57	18

Table 16: Multi-Family CO_2 Emissions Reductions Across End Uses Electrified

	All Electric New Construction	Existing Home Full Electrification	Existing Home Heating Electrification	Existing Home Water Heat Electrification
1st Year % Reduction	31%	31%	28%	57%
20-Year % Reduction	53%	53%	50%	71%
20-Year Tons of Reduction per Apartment	45	45	32	12

As discussed in Chapter 3, these results are based on long-run marginal emissions rates forecast for the state of Illinois by the National Renewable Energy Laboratory's Cambium model. They are based on a scenario in which the state requires 95% emission reduction from the grid by 2050, which is the best proxy – among the NREL scenarios one can select – for the expected emissions reductions under the 2021 Illinois Climate and Equitable Jobs Act (CEJA). However, even under NREL's "mid-case" scenario which does not yet reflect the expected impacts of CEJA, electrification would reduce emissions by roughly 60% from water heating electrification and by about one-third for all other electrification scenarios over the next twenty years.

Chapter 5 Conclusions

The results of our analysis indicate that all forms of electrification of single-family homes and individually metered multi-family homes with forced air heating systems (i.e., furnaces) and/or individual gas water heaters will save money. Energy bills will be lower in the very first year. Total energy costs savings over a twenty-year period will be very large – in excess of $20,000 in some cases.

The study also finds that electrification can significantly reduce greenhouse gas emissions, with 20-year reductions ranging from roughly 50% to 70%.

Looking forward we anticipate the economics for electrification will improve. We expect this would be primarily driven by a reduction in costs for electrification conversions. It is very likely that as cold climate heat pumps gain market share, cold-climate heat pump-based system costs will decline while efficiency and performance in cold temperatures improves relative to what is represented in this study. Additional interventions, such as building performance standards and additional utility, City of Chicago and/or other incentives to reduce the costs for electrification upgrades will also improve household economics and catalyze the market.