A Case for Rapid Building Electrification in New York

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Abstract

This white paper introduces the basics of all-electric buildings and delves into myriad reasons related to climate, health, costs, and economy to make the case for New York State to move full steam ahead, without delay, towards making electricity the principal energy source for powering its residential, commercial, and public buildings while rapidly weaning itself off on-site combustion of fossil fuels such as fossil methane gas and fuel oil.

Motivation and background: What's this about?

The most recent IPCC report[2] warns in no uncertain terms that the earth is perilously close to crossing critical global warming thresholds to reach irreversible climate tipping points that would trigger catastrophic run-away events like collapse of Greenlandic and Antarctic ice-sheets, massive methane releases from arctic permafrost, and shutdown of major ocean currents like the Gulf Stream. Such events will make large swaths of the world's populous areas uninhabitable and completely submerge some of them under rising seas. We are already witnessing unprecedented extreme weather, storms, floods, droughts, and fires driven by just 1.2° C of warming over preindustrial times. Without immediate transformative action, we can expect 2.7° C or more of warming by the end of the century, *within our young children's and grandchildren's lifetime*! This will result in climate disasters exponentially more destructive to life and property compared to today's, and New York state is in the crosshairs of the climate crisis[3].

It has been established beyond doubt[2] that climate change is being driven by continued release into the atmosphere of greenhouse gasses (GHGs), primarily carbon dioxide (CO_2), from burning fossil fuels like coal, fossil methane gas (*the product marketed as "natural gas" is 90-99% methane*), and liquid hydrocarbons like gasoline and diesel derived from petroleum. In order to avoid the most catastrophic impacts of climate change, we must rapidly and urgently[2] transition our energy systems to carbon-free sources.

Climate change is driven by cumulative GHG emissions; since pre-industrial times, the CO_2 concentration in the atmosphere has risen from 280 parts per million (PPM) to 418 PPM, an almost 50% increase[4]. For reference, the earth has not experienced atmospheric CO_2 concentrations of more than 400 PPM in the last three million years[5], which is 2.6 million years before humans evolved! United States, with about 4% of the world's population, is the source of

[1] Dr. Gupta's research areas include energy, materials, and decarbonization, in which he has several publications as well as one issued and three pending patents. He was a co-editor of the *Springer* volume, *High Performance Computing in Power and Energy Systems*. The views expressed here are those of the author and do not reflect IBM's position.
[2] Climate Change 2021, the Physical Science Basis, summary for policymakers; https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf
[3] States at Risk: New York; https://statesatrisk.org/new-york
[4] The Keeling Curve; https://keelingcurve.ucsd.edu/
[5] How the world passed a carbon threshold and why it matters? https://e360.yale.edu/features/how-the-world-passed-a-carbon-threshold-400ppm-and-why-it-matters

a quarter[6] of this anthropogenic increase in atmospheric CO_2. In addition to being the world's largest contributor to GHGs, the United States' status as one of the world's most prosperous and technologically advanced nations makes it a strong candidate to lead the world in energy transition. In the absence of a meaningful federal climate policy, states must be at the forefront of the fight against climate change, and many are. New York's Climate Leadership and Community Protection Act (CLCPA)[7] is a testament to it's prudent climate commitments. Thankfully, the current state of the technology not only makes the energy transition feasible and cost-effective, but also promises to be an engine for economic growth[8] and job creation.

Why all-electric buildings?

Buildings are responsible for about a third of New York State's total GHG emissions[9], with space and water heating being the largest contributors. Therefore, on the road to decarbonizing NY's economy and meeting CLCPA's legally binding targets, it is essential to reduce and eventually eliminate these emissions. Decarbonization of New York buildings is also critical for United State's climate goals because the state has by far the highest building-related emissions in the country[10] **[Figure 1]**.

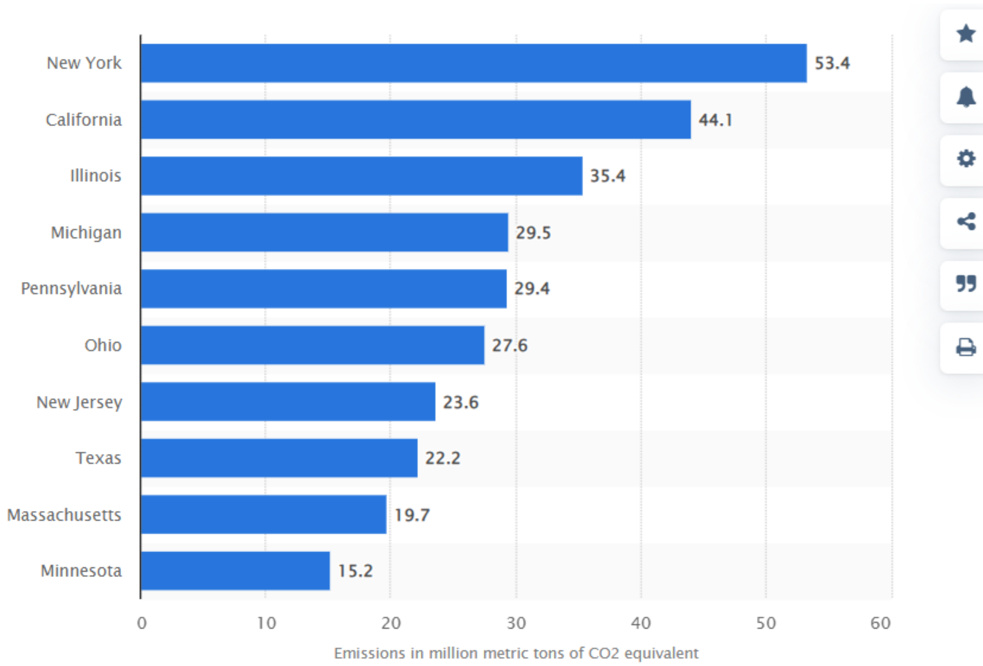

Figure 1: States with the highest GHG emissions from buildings (2017 data).
Source: https://www.statista.com/

[6] Who has contributed most to global CO_2 emissions? https://ourworldindata.org/contributed-most-global-co2
[7] Climate Leadership and Community Protection Act; https://eany.org/wp-content/uploads/2019/10/clcpa_fact_sheet_0.pdf
[8] Job creation during a climate compliant global energy transition across the power, heat, transport, and desalination sectors by 2050; https://www.sciencedirect.com/science/article/pii/S0360544221019381
[9] Carbon-neutral buildings: Day 1 presentation; https://www.nyserda.ny.gov/All-Programs/Carbon-Neutral-Buildings
[10] Greenhouse gas emissions from buildings in the United States in 2017, by select state; https://www.statista.com/statistics/1089355/ghg-emissions-buildings-us-by-state/

It is widely accepted[11] that phasing out the use of on-site fossil fuels such as heating oil and methane gas and shifting to electricity as the sole energy source for buildings, while simultaneously pursuing weatherization, energy efficiency, and improved building codes, is the only feasible path to decarbonizing building operations. Once electrified, the GHG emissions associated with buildings will decline as more distributed and centralized carbon-free sources of electricity are added to the grid.

Methane gas is the dominant fossil fuel used inside buildings. Beyond releasing CO_2 upon combustion, methane is a potent GHG itself, with 85 times the heat-trapping capacity of CO_2 in 20 years. Improved detection and measurement techniques have recently found[12] that as much as 4-9% of all fossil methane is lost to fugitive emissions from leakage during extraction, processing, distribution, and use. Studies on urban distribution[13] and residential[14] leaks have found alarmingly high and previously underestimated rates of fugitive emissions. With proper accounting of such leaks, scientists are increasingly reaching the shocking conclusion that overall, methane is likely a worse contributor to climate change in the short term than even coal.

Is it only about climate change?

While climate change is the primary motivation behind the interest in advanced building electrification technologies, adopting them also confers significant health and safety benefits.

Health

United States is among the top ten nations leading in deaths due to air pollution, which results in 8-9 million deaths[15] world-wide each year. On-site use of fossil fuels in buildings brings this deadly pollution into our homes and communities, and eliminating this pollution source would yield dramatic benefits[16] to public health and considerable reduction in healthcare costs.

According to US Energy Information Administration[17], the top three uses of fossil gas in US households are space heating (69%), water heating (26%), and cooking (3%). Although cooking accounts for a small fraction of household gas use, the gas industry heavily promotes[18] gas cooking in order to gain a foothold into residences and capture the much larger space and water heating segment. Cooktops are the only appliance category for which the users may have

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[11] Decarbonizing US buildings; https://www.c2es.org/document/decarbonizing-u-s-buildings/
[12] Methane leaks erode green credentials of natural gas; https://www.nature.com/articles/493012a
[13] Majority of US urban gas leaks unaccounted for in inventories; https://www.pnas.org/content/118/44/e2105804118
[14] Methane and NO*x* emissions from natural gas stoves, cooktops, and ovens in residential homes; https://pubs.acs.org/doi/10.1021/acs.est.1c04707
[15] Deaths from fossil fuel emissions higher than previously thought; https://www.seas.harvard.edu/news/2021/02/deaths-fossil-fuel-emissions-higher-previously-thought
[16] Reducing emissions to lessen climate change would yield dramatic health benefits by 2030; https://climate.nasa.gov/news/3134/reducing-emissions-to-lessen-climate-change-would-yield-dramatic-health-benefits-by-2030/
[17] Detailed household natural gas and propane end-use consumption totals; https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce5.2.pdf
[18] The gas industry is paying Instagram influencers to gush over gas stoves; https://grist.org/food/the-gas-industry-is-paying-instagram-influencers-to-gush-over-gas-stoves/

a fuel preference beyond cost considerations. Leaked industry documents[19] have shown that this is something that the gas industry is acutely aware of, and therefore, spends the bulk of its promotional effort on fostering an emotional attachment with gas cooking.

Although the fossil gas industry misleadingly promotes its product as "clean," numerous studies have shown that gas stoves generate unsafe levels of indoor pollution and pose a serious health risk while avoiding regulatory scrutiny because there are no federal or NY State regulations on indoor air pollution. Particulate matter, implicated in respiratory and cardiovascular diseases, is the most harmful pollutant released by gas burners[20]. A meta study combining results from 41 different studies found that children living in homes with gas stoves had a 42 percent higher incidence of Asthma[21], primarily due to nitrogen oxides released by burning gas. Carbon monoxide[22] and formaldehyde are other unhealthy pollutants[23] produced by gas stoves. Gas stoves are often responsible for indoor pollution levels that would be illegal outdoors, which is troubling because most people spend more time at home than anywhere else. Lower-income families and those with smaller living spaces or kitchens without effective range hoods face disproportionately high health risks from such indoor pollution.

Safety

During the decade of 2010-2019, the US suffered 1411 major gas-related incidents[24] through its pipeline network, roughly one every three days. These resulted in 109 deaths, 606 serious injuries, and $3.5 billion in property damage. This data from Pipeline and Hazardous Materials Safety Administration includes *only* the incidents that involved more than $50,000 in damages or resulted in a fatality or in-patient hospitalization. It also excludes all deaths, injuries, and property damage due to behind-the-meter leaks (i.e., all gas-leak related house fires and explosions), which happen fairly regularly, like in Brewster[25] (February 2, 2022) and in Brooklyn[26] (February 5, 2022) just in the New York City metro area within a week.

In essence, continued distribution and use of fossil gas in buildings not only exacerbates the climate crisis, but it also undermines New Yorkers' health and safety.

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[19] American Gas Association Advocacy Training Workshop 2018; https://www.documentcloud.org/documents/6766829-NG2018-Conference#document/p4/a549298
[20] Compilation of published PM 2.5 rates from cooking, candles, and incense for use in modeling of exposures in residences; https://www.osti.gov/biblio/1172959
[21] Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children; https://academic.oup.com/ije/article/42/6/1724/737113
[22] Carbon monoxide poisoning: Gas-fired kitchen ranges; https://www.abe.iastate.edu/extension-and-outreach/carbon-monoxide-poisoning-gas-fired-kitchen-ranges-aen-205/
[23] Gas stoves can generate unsafe levels of indoor pollution; https://www.vox.com/energy-and-environment/2020/5/7/21247602/gas-stove-cooking-indoor-air-pollution-health-risks
[24] Gas pipeline incidents; https://climatenexus.shinyapps.io/GasExplorer/
[25] Gas-fed fire destroys a two family home in Brewster; https://www.lohud.com/picture-gallery/news/local/2022/02/03/gas-fed-fire-destroys-two-family-home-brewster/6643137001/
[26] Two homes destroyed, 3rd damaged in fire, gas explosion in Brooklyn, FDNY says; https://newyork.cbslocal.com/2022/02/05/fdny-brooklyn-explosion-homes-on-fire/

Technology overview: What are the alternatives to gas (and heating oil)?

Cold-climate heat pump technology[27] is an effective low-carbon pollution-free alternative to gas furnaces and would be the cornerstone of building electrification in the northeastern United States, because space heating accounts for the most gas used in buildings in this region. Instead of generating heat, heat pumps transfer heat in or out of the buildings, depending on the season. This flexibility allows a heat pump to provide *heating and air conditioning* with a single system; many heat pumps are capable of providing hot water as well. Similarly, attractive all-electric options for hot water and cooking are also available. The remainder of this section discusses electric alternatives to the top three household uses of fossil methane gas.

Heat Pumps

Heat pumps are multi-function indoor climate control appliances for both heating and cooling, with some models including water heating or preheating function as well. Based on the medium that acts as the source or the destination of the heat moved into or out of the building, there are two main types of heat pumps: *Air Source Heat Pumps* (ASHPs) and *Ground Source Heat Pumps* (GSHPs), also referred to as *geothermal* heat pumps. As the names suggest, an ASHP **[Figure 2]** transfers heat between a building and ambient air (a conventional air-conditioner is a one-way ASHP), and a GSHP **[Figure 3]** transfers heat between a building and nearby ground, where the temperature below the frost line is steady year-round.

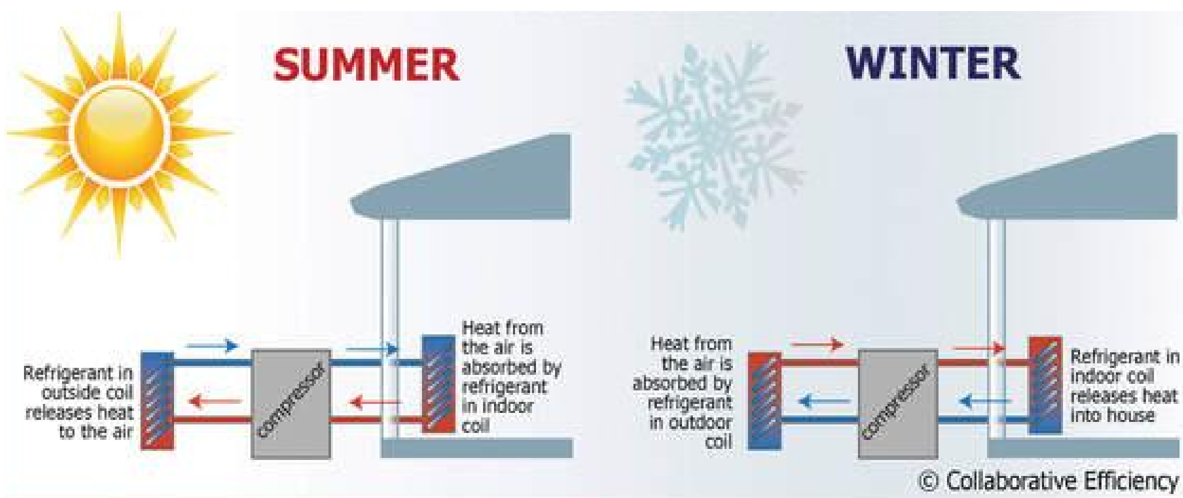

Figure 2: A schematic showing how an ASHP provides all-weather climate control.
Source: https://www.lamorteelectric.com/

Air Source Heat Pumps: In recent years, several manufacturers have started offering a new generation of *Cold-Climate Air Source Heat Pumps* (ccASHPs) based on inverter-driven variable speed compressors. Heat pumps also include optional auxiliary resistive heat to maintain comfort during very cold weather. The efficiency of ASHPs varies with weather conditions and declines with increasing humidity and decreasing temperature. Field tests of

[27] Heat pumps: A practical solution for cold climates; https://rmi.org/heat-pumps-a-practical-solution-for-cold-climates/

ccASHPs in Minnesota[28] and Alaska[29] have shown that these systems maintain effectiveness upto -10° F while reducing overall energy use, with supplemental heat kicking in below 5-10° F as needed. Note that the most recent ccASHPs[30] offer even more versatility and better performance than those used in the aforementioned studies. NYSERDA estimates[31] that New Yorkers can expect a 50% average efficiency gain over fuel-based systems.

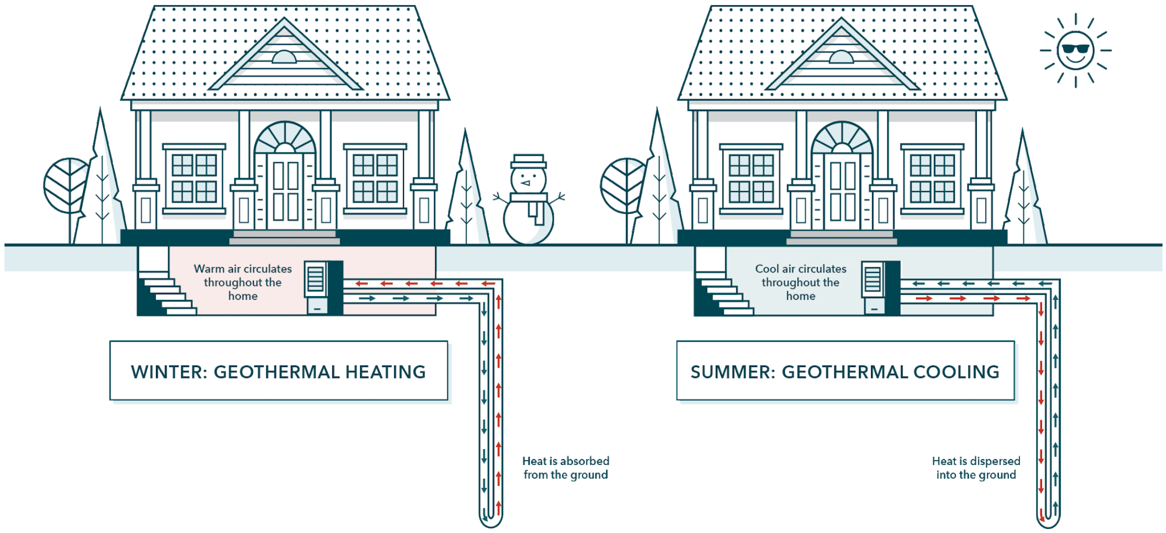

Figure 3: A schematic showing the heating and cooling operations of a GSHP.
Source: https://dandelionenergy.com

Ground Source Heat Pumps: GSHPs are remarkably efficient and work well in all weather conditions due to the stable underground temperature. A properly sized system does not lose much efficiency as temperature drops, although auxiliary heat may still be occasionally deployed when the heating load of the building exceeds the capacity of the heat pump. GSHPs consume up to three times less energy than conventional heating methods. In cooling mode, they are 50% more efficient than typical air conditioners, and thus help reduce the summer peak load on the electric grid. Their low energy consumption and the ability to work well in extreme cold make them the best space heating option in the coldest areas of upstate New York.

Both GSHPs and ASHPs can either be ductless (also known as *mini split*) with a single outdoor or geothermal heat-exchange unit supporting multiple indoor air-handling units, or they can support a central forced air duct network. Heat pumps paired with hydronic heat distribution (hot/cold water circulation) in the building are also available, but mostly in Canada and Europe at this time. NYSERDA has prepared a detailed residential heat pump planner[32].

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[28] Cold-climate Air Source Heat Pumps final report; https://www.mncee.org/cold-climate-air-source-heat-pump-final-report
[29] Air source heat pump potential in Alaska; http://cchrc.org/media/ASHP_SE_Report.pdf
[30] Best heat pumps for cold climates; https://www.arcticheatpumps.com/cold-climate-heat-pump-overview.html
[31] Keep your home comfortable all year long; https://cleanheat.ny.gov/assets/pdf/CHC-SFR-HP-buyingguide-br-1-v3_acc.pdf
[32] Heat Pump Planner: Clean heating and cooling options for homes; https://sustainablewestchester.org/wp-content/uploads/2021/08/heat-pump-planner-sw_compressed.pdf

Water Heaters

After space heating, hot water accounts for the second most amount of gas used in buildings. Many heat-pump based space heating and cooling solutions, especially GSHPs, include a hot water subsystem. These heat pumps include a secondary heat exchanger called a *desuperheater* that transfers waste heat from the condenser unit to a water preheating tank. The main hot water tank draws this preheated water and uses much less energy than heating water from scratch to deliver domestic hot water at the preset temperature. This is an extremely efficient process and can usually satisfy nearly all hot water needs in the summer for free.

In addition to water heaters coupled with heat pumps for space heating and cooling, stand-alone heat-pump based electric water heaters are also available and are becoming increasingly popular. These water heaters have a small built-in heat pump to transfer heat from ambient air into the water to produce domestic hot water using only about a third of the energy of conventional water heaters. Their placing must take their modest compressor noise, need for some air circulation, and space cooling effect into account.

Finally, there are conventional electric water heaters that use resistive heating. These are less expensive than gas-powered water heaters, both in equipment and installation cost, and are 100% efficient (heat-pump water heaters are up to 300% efficient). In contrast, any gas-powered heating appliance inevitably loses some heat while venting the hot exhaust. However, any emissions reduction potential of resistive water heaters relies on a high fraction of carbon-free sources in the energy mix of the electrical grid.

Ovens and Cooktops

Modern electric cooktops are sleek and elegant, energy efficient, non-polluting, and come in price ranges similar to comparable gas ranges. Their flat ceramic or tempered glass cooking surface is a breeze to clean. In cooking ranges, these cooktops are paired with ovens equipped with electric heating elements. Electric ovens tend to have slightly longer preheating times compared to their gas counterparts, but yield more precise and even temperatures resulting in a superior regular as well as convection baking outcome. The cooktops can employ two completely different heating mechanisms, even though they are mostly indistinguishable in appearance **[Figure 4]**. Both are vastly superior to and faster than the older electric cooktops with an external spiral coil or heating element.

Induction Cooktops: Induction cooktops generate no heat at all on their own; instead, they produce a powerful pulsating magnetic field. A magnetic cooking vessel made of cast iron or magnetic stainless steel heats up from the rapid magnetization-demagnetization cycles. A related drawback is that common aluminum-based cooking utensils cannot be used and additional purchase of cookware with magnetic bases may be required. The key advantages of induction cooktops are that they are very energy efficient and twice as fast as gas stoves because the heat is generated directly in the cooking utensil itself.

Radiant Cooktops: The semi-transparent ceramic cooking surface of a radiant cooktop has a resistive coil underneath that heats up and glows when turned on. Heat is transmitted to the cooking surface and to the cooking utensil primarily as infra-red radiation. Most radiant cooking ranges include at least one high-powered (around 3000 Watts) “burner” for quick heating or boiling. Radiant cooktops tend to be less expensive than induction cooktops.

Figure 4: *Left:* A 30” *induction* range with 5.4 cu. ft. convection oven, $1098 at Home Depot. *Right:* A 30” *radiant* range with 6.3 cu. ft. convection oven, $798 at Home Depot.

Will all-electric buildings cost more?

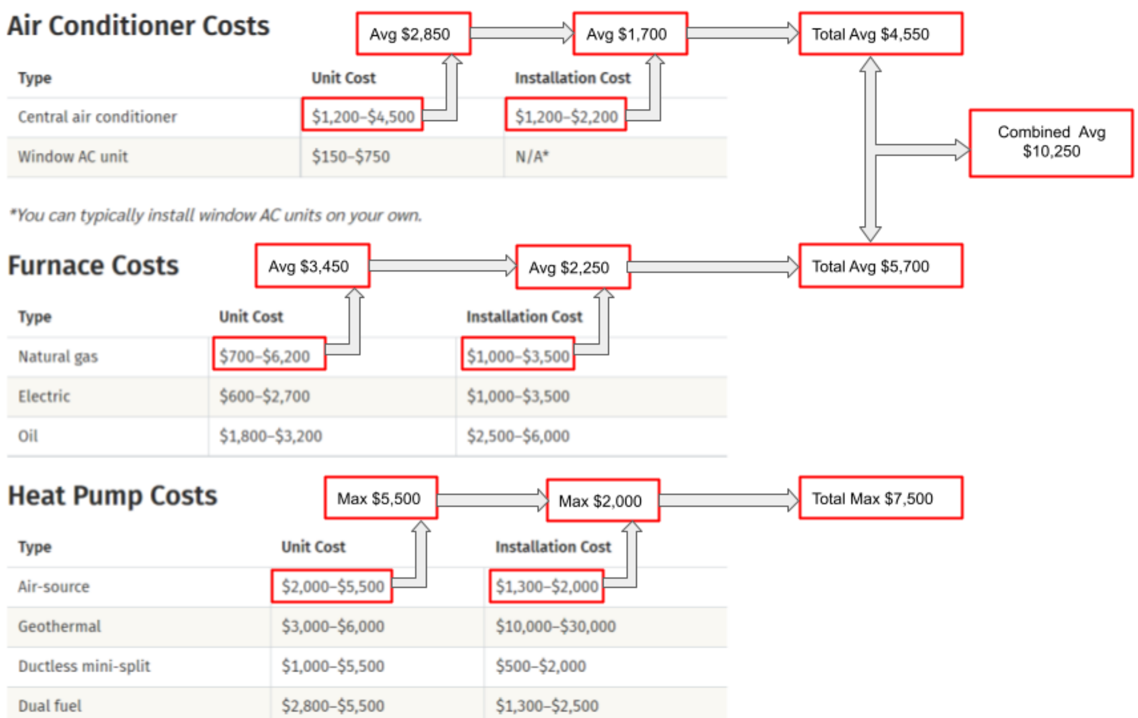
Before directly addressing the cost, a quick word on implicit biases. Implicit biases[33] delay climate action because (1) we tend to *underestimate exponentially growing threats*, as we did before the first wave of Covid-19 hit the US, (2) we get used to and tend to *ignore ongoing harm*, like nearly 2000 deaths[34] and $22 billion in health impacts each year in New York from burning fossil fuels in buildings, and (3) we tend to *overestimate the cost* of action or switching to new ways of doing things. This section focuses on the third point.

A rational and principled approach to examining the cost of all-electric buildings must include the following two elements: First, the cost of any climate action, including that of building electrification, must be weighed against the *near-term health costs* and the *long-term cost of damages* from climate inaction. Secondly, instead of simply assuming that electrification would be expensive, we must ask that in *new construction*, (1) why would it cost more for electricity to supply all the energy when the costs associated with *gas distribution line extension, piping, plumbing, metering, leak detection*, etc. are actually being eliminated? And, (2) why would a *single heat pump* cost more than *installing separate heating and cooling systems*? A quick answer to both questions is, “It doesn’t,” especially when gas hookup and plumbing costs are

[33] How brain biases prevent climate action; https://www.bbc.com/future/article/20190304-human-evolution-means-we-can-tackle-climate-change
[34] What is the health impact of buildings in your state? New York; https://rmi.org/health-air-quality-impacts-of-buildings-emissions#NY

also factored in. Additionally, it is an irrefutable fact that the cost of any new technology falls rapidly with mass adoption.

The reality is that installing modern electric heating, cooling, hot water, and cooking equipment in new construction, or near the end-of-life of existing equipment, is *not more expensive*[35] than the equivalent gas-powered equipment, unless a GSHP is installed. The cost of cooking and water heating appliances is comparable (heat-pump water heaters are more expensive) to that of similar gas-powered appliances. Electric clothes dryers are actually cheaper than gas-fired ones. It should be noted though, that in existing homes, electrification can incur additional weatherization and wiring (for 240 V circuits) costs, if needed. The remainder of this section focuses on the costliest and the most energy-intensive equipment, the HVAC system, in the context of *new residential construction* where installation costs are more predictable. Evaluation of system options and costs for commercial[36] buildings have shown similar results.



Air Conditioner Costs

Type	Unit Cost	Installation Cost
Central air conditioner	$1,200–$4,500	$1,200–$2,200
Window AC unit	$150–$750	N/A*

You can typically install window AC units on your own.

Furnace Costs

Type	Unit Cost	Installation Cost
Natural gas	$700–$6,200	$1,000–$3,500
Electric	$600–$2,700	$1,000–$3,500
Oil	$1,800–$3,200	$2,500–$6,000

Heat Pump Costs

Type	Unit Cost	Installation Cost
Air-source	$2,000–$5,500	$1,300–$2,000
Geothermal	$3,000–$6,000	$10,000–$30,000
Ductless mini-split	$1,000–$5,500	$500–$2,000
Dual fuel	$2,800–$5,500	$1,300–$2,500

Figure 5: A comparison of a high-end ASHP and average conventional HVAC installation. *Source:* https://www.thisoldhouse.com/

Air Source Heat Pump Versus Conventional HVAC

Unsurprisingly, a ccASHP-based climate control solution in new construction is not more expensive than installing separate systems for heating and cooling of equivalent quality. This can be readily confirmed by looking up current equipment and installation costs. A price

[35] The economics of electrifying buildings; https://rmi.org/insight/the-new-economics-of-electrifying-buildings/
[36] Electrification of commercial and residential buildings; https://www.communityenergyinc.com/wp-content/uploads/Building-Electrification-Study-Group14-2020-11.09.pdf

comparison chart[37] based on national averages from a popular home improvement site is included here **[Figure 5]**; it is representative of cost estimates from other sources as well. The comparison shows a conventional HVAC system in a typical 2500 square feet home to be costlier than an ASHP. This conservative comparison uses the average air conditioner and furnace costs, but the highest ASHP costs because we must assume that high-end ASHPs suitable for cold climates would be required in most parts of the state. These estimates exclude ductwork, which is a part of any central forced-air system. Note that the prices vary by region, and all prices are likely to be higher in New York relative to the national average—substantially so in New York City, Long Island, and Westchester county. However, the relative cost comparison between ccASHP and traditional HVAC still stands. In colder regions, ASHP units will likely be much larger than conventional ACs for similar buildings, still their cost is unlikely to exceed the combined cost of conventional heating and cooling systems, which would incur additional gas hookup and plumbing costs.

Dandelion Geothermal Geothermal heating, cooling, and domestic warm water system $18,000 - $25,000 base price	VS	Natural Gas Natural gas furnace, central air conditioning system, and domestic water heater $15,500 base price
$1,532 - Heating $295 - Cooling **$1,827 Total Costs**	Yearly Operating Cost	$1,602 - Heating $512 - Cooling **$2,114 Total Costs**
$50	Yearly Maintenance Cost	$300
$37,540	20 Year Operating Cost + Maintenance Cost	$48,280
$55,540 - $62,540	Total 20 Year Price	$63,780
$1,240 - $8,240	**Savings Over 20 Years**	$0
$0 down financing available, starting at $150/month	Financing	Financing not always available via contractor

Dandelion Geothermal Geothermal heating, cooling, and domestic warm water system $18,000 - $25,000 base price	Fuel Oil Fuel oil furnace, central air conditioning system, and domestic water heater $15,500 base price
$1,532 - Heating $295 - Cooling **$1,827 Total Costs**	$2,896 - Heating $512 - Cooling **$3,408 Total Costs**
$50	$300
$37,540	$74,160
$55,540 - $62,540	$89,660
$27,120 - $34,120	$0
$0 down financing available, starting at $150/month	Financing not always available via contractor

Figure 6: Installation and operating cost comparison of GSHP and conventional HVAC systems. *Source:* https://dandelionenergy.com

Cost of Ground Source or Geothermal Heat Pumps

GSHPs are significantly more expensive to install than ccASHPs and traditional HVAC systems; nevertheless, they are an attractive option for many homeowners. GSHPs have the lowest energy consumption and operating costs of any HVAC system, and therefore the highest emissions reduction potential. In USDA Zone 3 and 4 locations in upstate New York, GSHPs are the best heating option because conventional HVAC systems would consume excessive amounts of fuel and ccASHPs would run at reduced efficiency and use supplemental heat for extended periods. Another advantage of GSHPs is that their replacement cost is similar to or

[37] How much does an HVAC installation cost? (2022); https://www.thisoldhouse.com/heating-cooling/22833797/hvac-installation-cost

lower than that of ASHPs and conventional HVAC systems because the costliest part of a GSHP installation is the ground loop, which has a life expectancy of 50–100 years.

For reference, an installation and operating cost comparison **[Figure 6]** of GSHPs with gas and oil furnaces for Westchester county is included. Note that this chart is based on oil, gas, and electricity prices prior to the recent rate increases that have led to projections of a 22–94% increase in fossil fuel users' utility bills, but only a modest 4–15% for electric heat customers. In the future, supportive federal and state policy measures such as rebates, sales tax exemption, and income tax credits would go a long way in reducing the cost of GSHPs by stimulating a positive feedback cycle of higher adoption rates and resulting price declines.

Energy-Efficient Construction and Building Codes

Building codes[38] that promote construction of energy-efficient buildings with a superior thermal envelope, typically achieved by improved windows, insulation, and sealing, not only reduce the operating cost of space heating and cooling equipment, but can also help lower the cost of equipment itself. The reason is that HVAC systems, including heat pumps, are sized based on the highest expected heating and cooling load of a building, and a smaller capacity unit would suffice for a highly efficient building. Therefore, energy-efficient construction practices must be pursued alongside building electrification to reduce costs and emissions.

Impact on jobs and economy

New York does not produce much fossil fuels, but the state produces the bulk of its electricity, whose already declining dependence on fossil fuels is set to reduce rapidly during the next decade. Every dollar shifted from oil and gas to electricity amounts to a net reinvestment in New York's economy, supporting growth in jobs and the economic output associated with the state's clean energy sector. This is a great reason for New York to electrify not only its buildings, but its transportation as well. There's credible evidence of job creation and investment in New York from building electrification; two of the recent success stories are highlighted below.

BlocPower [https://www.blocpower.io/] is a climate-tech startup that was founded in Brooklyn, NY in 2014. To date, the company has retrofitted more than 1,200 apartment and commercial buildings in disadvantaged communities in New York City, with projects underway in 26 cities, including Philadelphia, Milwaukee, Baltimore, Oakland and more. BlocPower's clean energy projects save customers 20-70% on energy costs. The company is growing rapidly and adding jobs. It is backed by top investors, including Kapor Capital, Andreessen Horowitz, The Goldman Sachs Urban Investment Group, and others. BlocPower is partnering with the city of Ithaca, NY to electrify the city's entire inventory of 6000 buildings by 2030.

Dandelion Energy [https://dandelionenergy.com/] was originally conceived at Google Alphabet's X innovation lab in Palo Alto, California in 2017. Now based in Mount Kisco, NY, the

[38] Building codes: A powerful yet underused climate policy that could save billions; https://www.forbes.com/sites/energyinnovation/2020/12/02/a-powerful-yet-underused-climate-tool-building-codes/

company perfected a vertical ground loop technique for GSHPs that reduces installation costs. Its founder, Kathy Hannun was named one of Fast Company's most creative people in 2018. Since installing it's first proprietary system in 2018 in upstate New York, the company has been growing and hiring steadily and has now expanded its operations into Connecticut, Massachusetts, and Vermont. The company recently brought a novel design of a ductless GSHP system to the market that will lower the costs and increase the versatility of GSHPs.

Summary and conclusions

Why act?

- We are in a *critical stage of the climate crisis*, somewhat similar to the February 2020 stage of the Covid-19 crisis. Our actions *today* will shape the climate trajectory for decades, even centuries.
- Effective and economical solutions are available; *political will*[39] is the *only* hurdle in the way. The USA and Australia lag other OECD nations in climate action.
- With federal climate policy in shambles, municipalities and states must take the lead; populous states like New York can make huge direct and indirect impacts.

Why buildings?

- Buildings account for a third of New York's emissions; *electrification* and *efficiency-enhancement* of buildings are cost-effective ways of reducing emissions that also have tremendous *health and economic benefits*.
- *New construction is low-hanging fruit*; a new all-electric building costs less than a similar building equipped for on-site fossil-fuel combustion, with the exception of buildings with Ground Source Heat Pumps (GSHPs).
- Given their extraordinary efficiency, low operating costs, and longevity, *GSHPs need policy support* to boost their adoption rate. In the coldest areas of New York, GSHPs are the optimum space heating solution.

Why now?

- Appliances last 10-15 years; buildings can last decades. Every new building with on-site fossil-fuel combustion is an *avoidable costly mistake* that locks in an unpredictable and polluting fuel for generations, or will require an expensive conversion in the future.
- Just like in the off-shore wind industry, New York is in a unique position to become a *regional leader* in all-electric building technologies. New York must seize this opportunity.

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[39] Climate change: A matter of political will; https://www.oecd.org/env/tools-evaluation/climatechangeamatterofpoliticalwill.htm