Building electrification: Steps to start now amid an uncertain future

By Val Jensen, Duncan Rotherham, ICF

Introduction

Coming out of President Biden's April 2021 Leaders Summit on Climate, countries from around the world committed to stronger climate action and underscored the urgency as they stepped up prior 2030 greenhouse gas emission reduction commitments. The United States has committed to reducing emissions up to 50% below 2005 levels by 2030 as part of its nationally determined contribution and Canada has committed to cut emissions 40% to 45% below 2005 levels by 2030.

As nations move to reduce emissions toward carbon neutrality by 2050, local and regional governments are pursuing a broad spectrum of aggressive actions to reduce energy-related greenhouse gas emissions—including measures aimed at buildings. Electrification is emerging as a key component of a market-based and policy-enabled strategy to achieve those goals. Fossil-fuel combustion attributed to residential and commercial buildings accounts for between 15% to 25% of economy-level greenhouse gas emissions, and advancements in efficient

electricity-powered technologies, such as air source heat pumps, hold great potential to decarbonize buildings. But electrification paired with low-carbon electricity is not the only viable decarbonization pathway; as utility and public sector leaders consider their options, they need to carefully address uncertainty about the cost and feasibility of building electrification before deeming it a universal solution.

There's no one-size-fits-all way to decarbonize or electrify an economy, due to widely varying local considerations, such as:

- Existing building stock and energy infrastructure
- Differing climates
- Technology applicability and uncertainty
- Subnational government policy, regulatory frameworks, and preferences

Utility and public sector leaders face an uncertain landscape at a time when many long-term decisions need to be made that will guide decarbonization efforts for years. The critical first step is to evaluate the existing landscape to determine where your jurisdiction can start on the path to building electrification without hindering your ability to follow a decarbonization roadmap that's not yet fully plotted. By answering the key questions outlined in this white paper, decision-makers will be able to identify electrification actions that can be taken now, avoid more challenging efforts until more detailed context and analysis is available, and get started on an effective path toward decarbonization.

Decarbonization is a binary decision. Electrification is not.

Many jurisdictions, such as California and New York, have set aggressive goals to reduce emissions from building energy use, and others appear imminent. Decarbonizing buildings, and the economy as a whole, is a binary choice: emissions are reduced to meet new targets and avoid the worst effects of climate change or they are not.

However, the decision to electrify building energy use is not binary. "To electrify or not to electrify" is not the question. Electrification is one potential lever to hasten decarbonization. The questions are how much, how fast, and where should you pull the lever. Most communities have driven emissions and energy-use reductions through energy efficiency programs and improvements in building codes and appliance standards for decades. Those efforts will continue to be an important lever—not to mention a source of lessons and tools to operationalize electrification efforts. Adopting low-carbon fuels for heating is a third lever.

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Yet, building electrification is emerging as a market-based and policy strategy to achieve carbon reduction goals. In most jurisdictions, we know that electrification will be at least part of the solution for buildings. We also know that electrification of much of the building sector, particularly in the existing building stock in cold climates, will be challenging and expensive. Other approaches to decarbonizing the building sector may be able to achieve the same level of decarbonization at the same or lower cost in parts of the market.

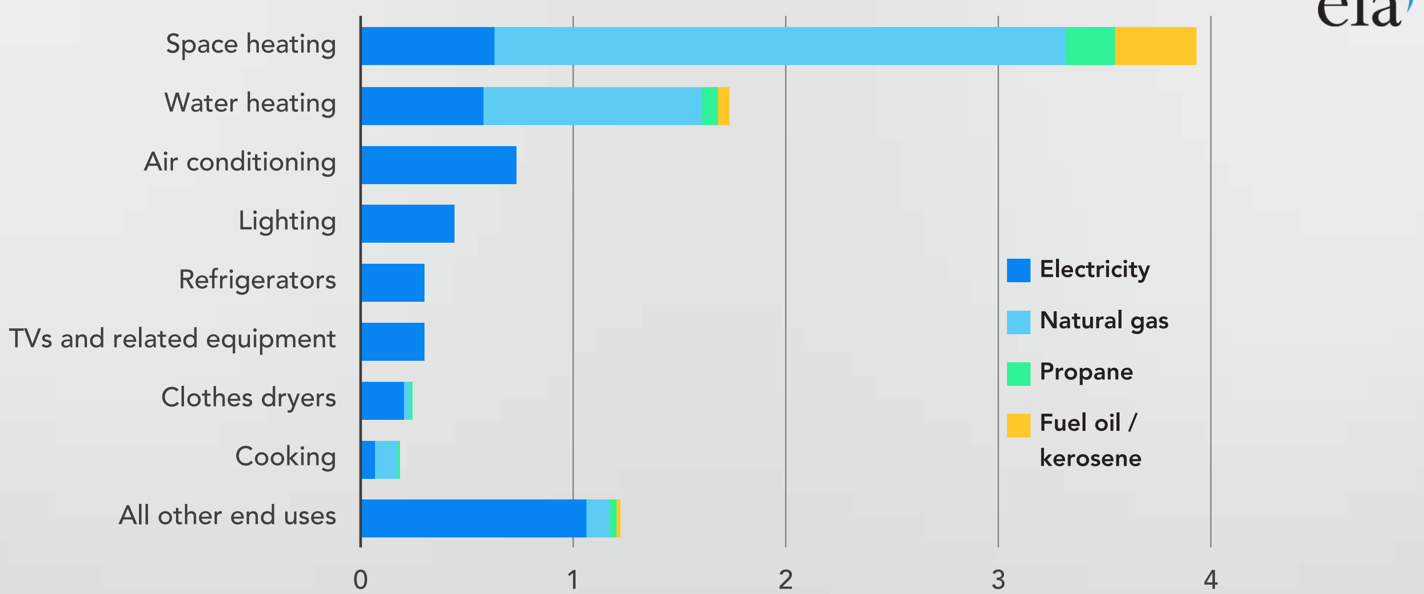
Geography, climate, existing local energy and building infrastructure, technology innovation, and governmental preferences will create a complex decision matrix for utilities to plot the best path forward. How can utilities, regional and local governments, and regulators manage the considerable uncertainty about the cost and feasibility? What can you do now to decarbonize through building electrification with such an unsure future?

Potential paths to building decarbonization

The first thing utilities, policymakers, and regulators can do is understand the potential paths to achieve building decarbonization, which are largely defined by the energy infrastructure serving their territory.

In most jurisdictions, buildings meet energy demand through a mix of power and natural gas infrastructure. Much of what goes on in industrial, commercial, and residential buildings is already electrified—lighting, computers and servers, air conditioning, entertainment systems, and more. However, two large end uses—space heating and water heating—are often served by fossil fuel-based systems, most commonly through a local natural gas utility system.

Figure 1: US household energy end-use consumption by fuel



Source: EIA 2015 Residential Energy Consumption Survey

Space heating and water heating account for nearly two-thirds of U.S. residential energy use, the majority of which is served by natural gas.[1]

This landscape of mixed energy sources and end uses provides measures that can be deployed at varying levels to tailor a decarbonization strategy. These approaches include:

- **Electrification:** Increasing the reliance of buildings on electricity to the full extent possible
- **Low-carbon fuels:** Relying on a greater supply of biogenic renewable natural gas (RNG) and hydrogen and less electrification of buildings
- **Mixed, or Diversified approach:** Leveraging various ratios of both options to electrify and use low-carbon fuels across the building sector

In addition to these approaches to decarbonize energy sources, energy efficiency is a critical universal mechanism to decarbonize the building sector. Most jurisdictions have been pursuing energy efficiency for years, but opportunities remain within existing conditions as well as through new efficiency measures that can be enabled by energy-use shifts like electrification or through the development of new, more efficient technologies like dual fuel and natural gas heat pumps.

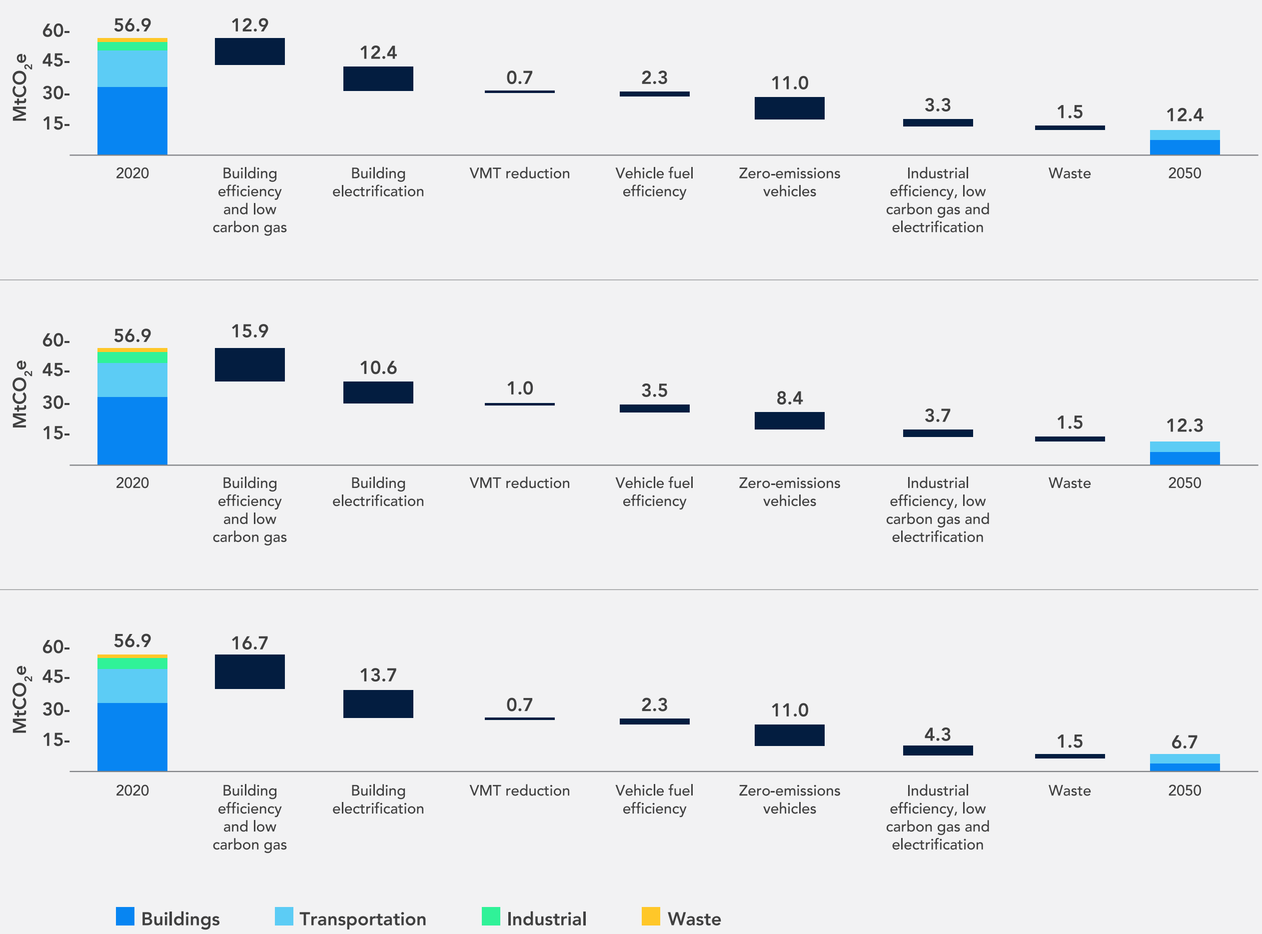
[1] https://www.eia.gov/energyexplained/use-of-energy/homes.php

Case in point: Building decarbonization measures in New York City

The achievable emissions reduction pathways in buildings—and associated timelines and costs—are unique to each territory. The recent report *Pathways to Carbon-Neutral New York: Modernize, Reimagine, Reach,*[2] which ICF supported, examined potential economy-wide emissions reductions and costs in New York City via different levers to decarbonize energy use in buildings.

Given the mix of variables in New York City, the study found that with aggressive energy efficiency, large reductions are achieved by using either an approach that emphasizes electrification reductions (25.3 MtCO2e by 2050 from 2020 levels) or that emphasizes low-carbon fuels (26.5 MtCO2e by 2050 from 2020 levels). However, an approach that relies on aggressive efficiency and electrification of building heating systems with large amounts of low-carbon gases for remaining needs results in the largest reductions (30.4 MtCO2e by 2050 from 2020 levels).

Figure 2: Emissions reductions by measure for each pathway



The Electrification Pathway relies heavily on electrifying building heating systems and all vehicle classes. The Law Carbon Fuels Pathway relies heavily on switching fuel sources to low carbon alternatives for building heating and heavy-duty transportation. The Diversified Pathway relies on both electrifying building heating systems and using low carbon gas for remaining building gas use.

Source: Pathways to Carbon-Neutral New York: Modernize, Reimagine, Reach; ICF analysis

The Diversified pathway was a clear winner in terms of level, velocity, and cost-effectiveness of decarbonizing buildings, and results in the deepest total abatement potential and lowest cost per ton of emissions reductions.

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[2] https://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/Carbon-Neutral-NYC.pdf

Pros and cons of electrification

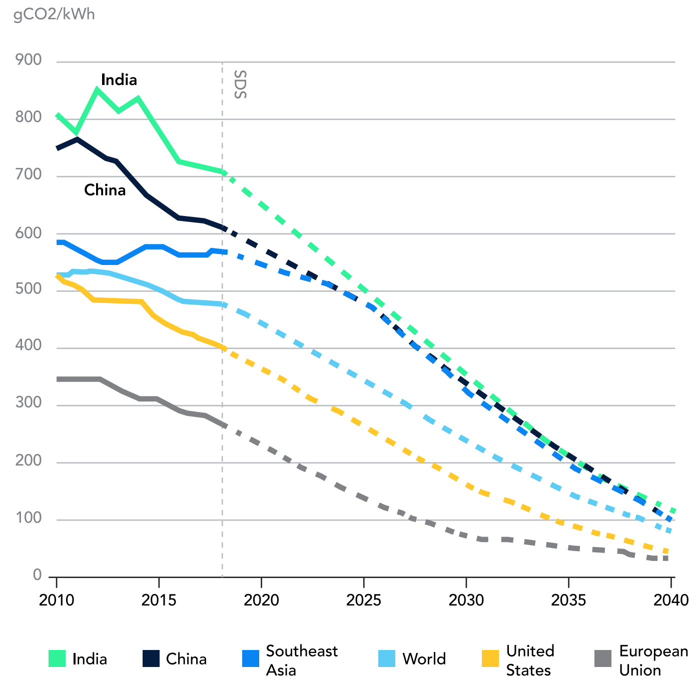
There is a vigorous debate about the cost, feasibility, and overall efficacy of building electrification as a means to decarbonize. The "Electrify Everything" theory[3] argues that renewable energy sources plus energy storage is the clearest path to zero-carbon energy use, and that the increased efficiency offered by electric heat pumps shifts the economics in favor of electric alternatives. The American Gas Association, on the other hand, argues that a pathway focused solely on policy-driven electrification would increase the average residential household energy-related costs of affected households, with the cost of the emissions reductions exceeding $570 per ton. This would be well above the costs of reducing emissions through the use of RNG and other low carbon fuels approaches.[4]

It's helpful to understand the pros and cons of electrification, keeping in mind that the scale of impact is a local matter that requires detailed local analysis informed by forward energy and environmental policy and targets.

Pros

- Rapid decarbonization of the power sector means electrified end uses tap into an increasingly less carbon intensive energy source. The International Energy Agency forecasts that the carbon intensity of U.S. electricity generation will plunge more than 80% from 2010 to 2040.
- Electric power-based technology innovations, such as air source heat pumps, offer an efficient way to heat and cool many building types. These technologies can enable smart, autonomous demand response and load flexibility systems in buildings, which can serve to limit increases in peak electric demand and offset the need for expensive generation and distribution infrastructure investments. There is a high level of confidence new technologies will emerge that make major building and power grid investments worth the time and cost.

Figure 3: Carbon intensity of electricity generation in selected regions in the Sustainable Development Scenario, 2000-2040



Source: International Energy Agency (IEA)

- Distributed renewable energy sources and energy storage technologies, combined with increasingly supportive regulatory and policy frameworks, are enabling microgrids to emerge as a solution to decarbonize, increase resilience, and lower energy costs.
- Given the current trend of shifting customer demand and expectations, electrification efforts coupled with clear emission reductions outcomes can enhance company reputations and brands. In practical terms, this can result in higher occupancy and rental rates for commercial and residential building owners leasing space or more profitable building sales to new owners.

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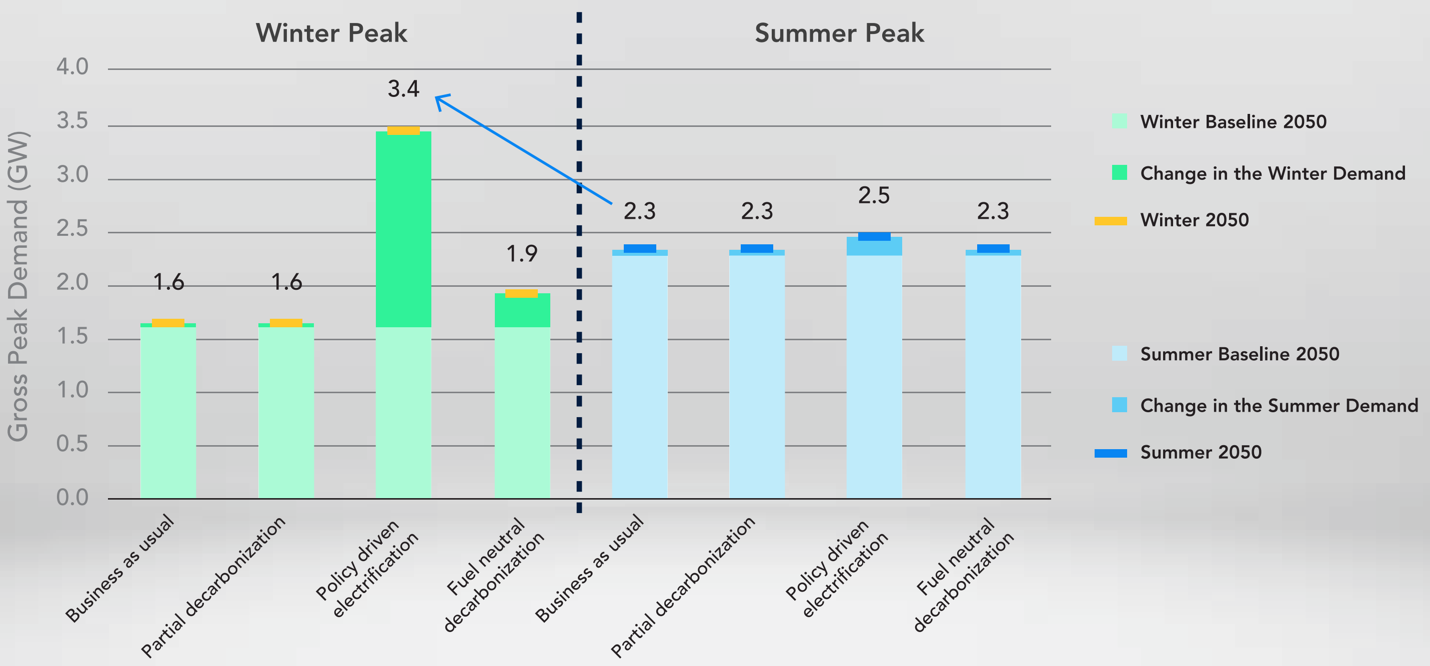
[3] https://e360.yale.edu/features/to-cut-carbon-emissions-a-movement-grows-to-electrify-everything

[4] Implications of Policy-Driven Residential Electrification, an American Gas Association Study prepared by ICF. AGA defined the cases to be evaluated, and vetted the overall methodology and major assumptions; Renewable Sources of Natural Gas, an American Gas Association Study prepared by ICF, https://gasfoundation.org/2019/12/18/renewable-sources-of-natural-gas/

Cons

- There are infrastructure hurdles with potentially costly ramifications. For example, retrofitting commercial buildings in major urban centers is extremely difficult. The Carbon-Neutral New York study finds that many smaller commercial buildings were built before 1945 with steam heating systems and limited space in mechanical rooms. In the United States, there are nearly 6 million commercial buildings and 46% of those buildings were built before 1979.[5] Outside of buildings, many local power distribution grids would require significant upgrades to handle the additional load from aggressive building electrification.
- In the residential sector, homeowners experience barriers to making home energy upgrades, from the financial to behavioral, and tactics such as rebates to target a single barrier are not effective for all homeowners.[6] In multifamily residences, the landlord-tenant cost split and the need for units to be vacated can blunt incentives to upgrade.
- While careful analysis is required to understand the full extent of any challenges, electrifying buildings can spur additional infrastructure costs if it's necessary to increase available generating capacity and upgrade the distribution system to meet a new peak in electricity demand. Figure 4 below, drawn from a decarbonization study ICF conducted for the District of Columbia[7], shows the 2050 annual peak demand shifts from the summer to the winter, with an increase of approximately 50% in the electrification case relative to the "business as usual" case. Although not shown, total annual kWh sales also increase by 22%.

Figure 4: Change in District summer and winter peak electricity demand requirements



Source: ICF analysis

- Technology innovations enable electrification, but the economics of those technologies depend on factors such as local climate and the mix of buildings by age and type. For example, the unit cost and efficiency of cold climate heat pumps is improving, but they still do not match the efficiency of air source heat pumps used in warmer climates.

[5] U.S. Energy Information Administration, Form EIA-871A of the 2018 Commercial Buildings Energy Consumption Survey

[6] Kevin J. Ketchman; David R. Riley; Vikas Khanna; and Melissa M. Bilec, "Survey of Homeowners' Motivations for the Adoption of Energy Efficiency Measures: Evaluating a Holistic Energy Assessment Program," Journal of Architectural Engineering, Volume 24 Issue 4, December 2018 https://ascelibrary.org/doi/full/10.1061/%28ASCE%29AE.1943-5568.0000310

[7] https://sustainability.wglholdings.com/wp-content/uploads/Technical-Study-Report-Opportunities-for-Evolving-the-Natural-Gas-Distribution-Business-to-Support-DCs-Climate-Goals-April-2020.pdf

Amid the uncertainty, one thing is certain

No one knows how cost-effective and feasible aggressive building electrification will be as a decarbonization pathway in the 2035–2050 time frame, but utility and public sector leaders need to make decisions now that will impact their options in that uncertain future.

There is one other known: Regardless of the best path to decarbonization that emerges in any given jurisdiction, some level of building electrification will be part of the solution.

Building electrification decisions to make now

No one-size-fits-all answer exists due to the wide array of local considerations, such as existing building stock and energy infrastructure, climate, uncertainty around technological advancements, subnational government policy incentives, and regulatory frameworks and preferences. However, there are questions that utility, government, and regulatory leaders can ask themselves now to start down the most beneficial path toward electrification.

A framework for action: Key questions to navigate the path forward

Remember: Building decarbonization is a binary decision; building electrification is a lever. When, where, how, and how much building electrification a territory pursues matters. To take action in the short term that sets up the best outcomes in the long term, it's important to complete an analysis answering questions on the following topics.

When?

When to start electrification efforts is the first among equal considerations. Once a building is built with natural gas or other nonelectric systems, it becomes exponentially harder and more expensive to electrify. It's best to start electrifying buildings when they are in design. Regions projecting high rates of new construction have a unique opportunity to implement affordable electrification that delivers serious decarbonization. Even if new buildings use fossil fuels, their design should offer the flexibility to switch energy sources at a future date. This optionality is not free but is of value; like any hedge, it offers insurance against uncertainty.

Factors that impact timing include:

- Is your area home to an aging power or gas infrastructure system that requires immediate upgrades, or can those investments be delayed? A territory with a modernized electric grid and newer, ample, non-emitting generating capacity paired against an aging gas distribution system could be more economical to decarbonize via rapid electrification rather than decarbonization of the gas system, particularly if the gas system requires significant upgrades to enable decarbonization measures such as hydrogen blending. The opposite is true in areas with aging, overburdened power infrastructure and modern gas infrastructure.
- Is a high number of new buildings planned in your area? Are there policies, incentives, and requirements in place to ensure new construction incorporates the most efficient, lowest-carbon options? Electrification retrofits, much like solar and energy efficiency, become harder as soon as a building is designed, even more so once it is built.
- What is the age of your equipment and when does stock turnover occur? With retrofits, you will get the most bang for your buck if you are able to get in on natural turnover cycles.
- What are the typical age ranges of buildings in your area? Is there a large percentage of renovations of older buildings projected in the near term, and are policies, incentives, and requirements in place to guide these renovations? A city with a newer building profile might already be relatively energy efficient, and could achieve greater emissions gains at lower cost in the near term by also focusing efforts on electrification of the local transportation sector—as transportation electrification has a lower impact on the grid, a higher impact on emissions reduction, and is cheaper and easier to achieve than building electrification.

To take action in the short term that sets up the best outcomes in the long term, it's important to complete an analysis answering questions of *when, where, how,* and *how much*?

Where?

Climate plays a major role in where building electrification can be most cost-effective and efficient. Territories in cold climates will see a variance in the performance of electrified technologies compared to warm climates and are more likely to have heating needs supported by a robust gas distribution system. However, "where" questions do not start and end with the climate. Location-based factors such as the current and future power generation sources in your area and the adequacy of power and gas distribution infrastructure serving a territory are relevant to determine where to electrify.

Key factors related to location include:

- How does the local climate impact peak loads for electricity and gas systems?
- How does the climate impact the effectiveness of available technologies?
- What is the carbon intensity of power generating-sources serving your area? Has your territory announced plans or goals to increase renewable energy or other low-carbon generation? Is it likely your area can benefit from large increases in solar or wind generating capacity in the future?
- What are the potential limitations of the existing regional power and gas transmission and distribution systems?

How?

While one city might be characterized by an abundance of single-family homes and small commercial buildings, the next could be defined by a dense tangle of large commercial and multifamily residential buildings. How electrification is—and even can be—pursued is defined by existing and planned building infrastructure. Building type is not the only "how" consideration, as average building age also correlates with what is feasible.

"How" should also consider energy equity. About a third of all households are economically challenged, with many of those living in rental housing. Unlike energy efficiency, through which measures like relatively cheap, high-efficiency lightbulbs could benefit all households, building electrification measures will include heating systems and EV chargers that cost thousands of dollars. Building owners, not renters, will decide when to install them. Increased energy costs to support electrification will have a greater impact on low-income households, while higher income households are most likely to adopt building electrification measures first to benefit from strong early incentives. Utility strategy should prioritize a least-cost path to avoid creating even greater burdens for low-income customers; policies and actions should ensure that building electrification works to advantage, rather than leave behind, vulnerable populations.

Factors that help you dig deeper into "how" include:

- Has your jurisdiction aggressively pursued energy efficiency? The cost of all forms of energy is expected to go up. Energy efficiency is typically the least expensive strategy and, therefore, should be the first action taken. How can energy efficiency gains be secured across building types before more extensive and potentially expensive decarbonization strategies are pursued? Can electrification unlock new forms and higher levels of energy efficiency that fossil fuel technologies cannot?
- Has your territory conducted a holistic electrification-potential study to understand the ramifications of pursuing multiple strategies in tandem? For example, there are opportunities and challenges related to pursuing the electrification of transportation and building heating systems in tandem.
- What is your lowest hanging fruit, in terms of cost and feasibility? Single-family homes with electric baseboard heat can be cost-effectively upgraded to air source heat pumps without impacting electric system peak loads. Electric baseboard heat in dense, multifamily buildings can be more difficult to retrofit. Single-family homes with heat from refined petroleum products and propane can also be cost-effectively upgraded to air source heat pumps, though such shifts could trigger costs related to peak demand for electricity.
- If your market relies on natural gas infrastructure systems, has it launched pilot programs to begin testing a transition to electrification or the use of low-carbon fuels? If not, pilot programs are a prudent first step to seek out cost-effective and optimal strategies to reduce greenhouse gas emissions.

- What is the adoption rate of EVs in your area, and how much will that shift energy demand from gasoline to electricity? Are policies and incentives in place to shift EV charging out of peak demand periods? Both vehicle and building electrification can tax the distribution grid, so measures should be taken to avoid these increases in electric load occurring at the same time and in the same places.

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How much?

Electrification may decrease costs for individual buildings but drive up costs for the communally shared power and gas infrastructure systems.

For example, assume more efficient, lower cost cold climate heat pumps enter the market, leading to a wave of upgrades from gas heating to electrified heating. The economics can appear great to homeowners before system costs are counted. If that cold climate territory has 2 GW of excess generating capacity above peak demand, and each new heat pump increases the peak-hour demand in a home by 10–12 kW, then the existing generating infrastructure could handle heating system electrification in 200,000 homes before reaching a new peak that requires building expensive new electric capacity. In general, assuming a summer peaking electric system, the more excess power capacity a system has above peak summer demand, the more building electrification a region can tolerate. Similar scenario planning can be done for distribution system capacity. Territories with ample capacity above peak summer demand can start the building electrification process now while having time to institute new energy efficiency and demand response programs.

Key factors related to extent include:

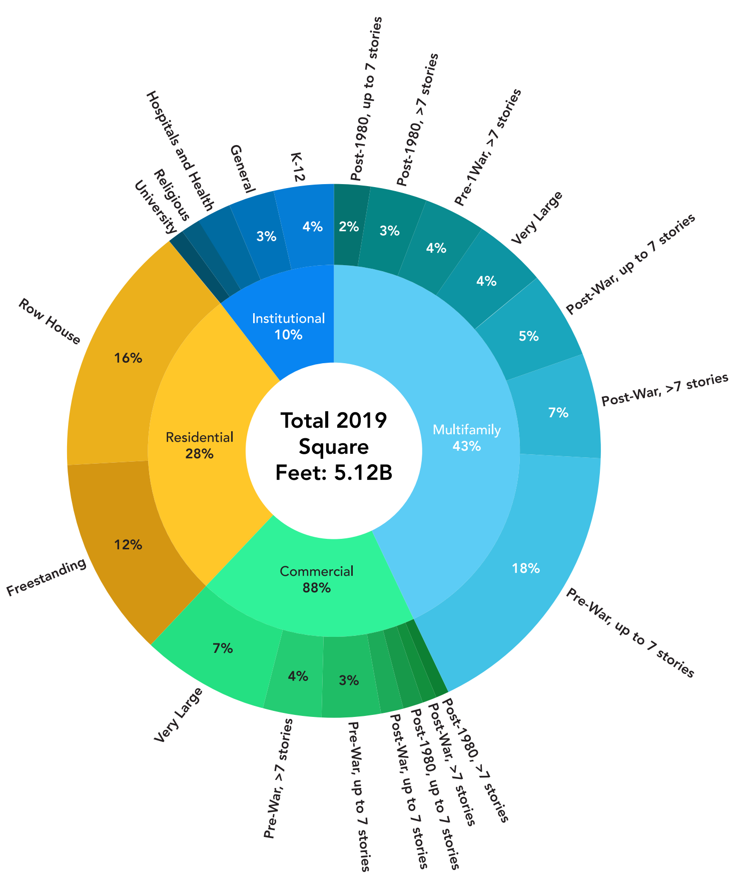
- How will electrification affect peak electric loads? Will new generating capacity and grid upgrades be needed? What will that mean for ratepayer costs?
- What is the outlook for new generating capacity coming online? New renewable energy resources combined with energy storage baseload capacity offer the most viable path to serve increased demand from building electrification while reducing carbon emissions. While renewable energy like solar and wind has become relatively inexpensive, storing power from those intermittent resources remains expensive.
- Does your territory have policies, regulations, and incentives in place to encourage the development of microgrids so that building owners can "self-serve" with a holistic building electrification solution when market conditions allow?
- Is your local electricity distribution system able to handle more load? Many residential circuits are not designed to handle the increase in load associated with more all-electric buildings and electric vehicles.

Asking the right questions is the hard part. Now get the right answers.

Technologies that don't yet exist will have an outsized influence in the long term, but we don't know when those disruptive innovations will arrive. We don't know when consumers will want to adopt them or if they will win political favor. That is the uncertain landscape utility, policy, and regulatory leaders face today at a time when many decisions need to be made in the short term that will guide decarbonization efforts for years.

Local considerations will create many different optimal paths to decarbonize, with varying degrees of electrification. As illustrated in Figure 5 below, New York City's one million buildings have a range of uses, ages, sizes, and classifications—and are served by existing gas and steam heating systems. Building electrification in New York will be more challenging and costly than in a less dense, land-rich city with newer, smaller, predominantly free-standing buildings.

Figure 5: NYC building stock, 2019



Source: Pathways to Carbon-Neutral New York: Modernize, Reimagine, Reach; ICF analysis

However, building electrification is at least part of the solution to decarbonize energy use, regardless of a territory's unique mix of local considerations.

Therefore, the action to take now is to determine where, when, and how your area can start on the path to building electrification, while preserving options until the landscape becomes clearer. You'll want to identify "no regrets actions" that will avoid inadvertently making decarbonization more challenging and expensive. For example, here is one scenario highlighting a series of "no regrets actions" a territory or utility could take that work in conjunction, allowing for optionality without steering it down an irreversible, suboptimal path:

1. Prioritize and incentivize energy efficiency upgrades, such as building envelope upgrades, to allow more buildings to right-size electrification and minimize cost and impacts on winter peaks.
2. Install air source heat pumps in any existing electric-heated buildings to reduce their demand.
3. Electrify as many buildings as possible until winter electric demand peak closely matches the summer peak.

Answer the key questions above to determine what actions can be taken now that are cost-effective, low-hanging fruit and to avoid pursuing trickier, more difficult efforts first.

Answering these questions requires deep analysis, planning, and strategy. ICF provides services to support jurisdictions in their efforts to emerge with the right answers:

- System and locational impact analysis
- Grid and environmental impact analysis
- Cost-effectiveness evaluation
- Market and opportunity assessment
- Program design, implementation, and evaluation
- Regulatory support
- Strategic planning

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Val is a specialist in the energy industry field with over 40 years of experience. As senior vice president for strategy and policy at Exelon Utilities, he oversaw technology and business strategy, supported policy, and coordinated strategy development for Exelon's operating utilities. As senior vice president for customer operations at Commonwealth Edison (ComEd), Val managed the development and delivery of customer-facing products and services, including the company's $250 million annual portfolio of demand response and energy efficiency programs.

Val is also a senior fellow with the ICF Climate Center. In this role, he provides compelling research and objective perspectives on a wide range of climate-related topics to help advance climate conversations and accelerate climate action.

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Duncan leads our electrification business and Canadian commercial energy operations. He's an expert in energy and carbon markets, focusing on climate action and decarbonization policy and planning for industry and utilities. With nearly 25 years of experience, he supports international, national, and sub-national governments in deploying climate and energy policy design. Duncan also oversees decarbonization analysis and corporate strategy development and implementation work with electric and gas utilities, oil and gas, and a broad spectrum of heavy industrials.

Duncan has been named to Canada's Clean50 list for 2021 in the Consultants and Enablers category. He holds a graduate diploma in Ecotoxicology from Concordia University and a bachelor's degree in Biology from the University of Victoria.

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