

Cooking Up Carbon Reductions: Equipment Upgrades and Fuel Switching Strategies to Reduce Emissions from Commercial Kitchens

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ABSTRACT

As the public and private sectors pursue aggressive goals for reducing greenhouse gas (GHG) emissions, commercial foodservice kitchens and restaurants face the challenge of forging new strategies and seizing opportunities to achieve such goals, while also meeting local and state regulations that support electrification as a leading decarbonization strategy. Since gas equipment is the standard for most commercial kitchens, lower carbon options for a decarbonized kitchen future may need to include gas fired as well as electric solutions. In this environment, commercial foodservice operators need practical, phased strategies to reduce operating costs and improve operational efficiency through upgrading to more energy-efficient equipment, adjusting start-up and shutdown schedules, and improving maintenance and cleaning schedules to support the goal of an efficient, low-carbon kitchen. Foodservice partners in the U.S. Department of Energy (DOE) Better Buildings Initiative are demonstrating how these steps can lead to smarter, healthier, and lower-carbon kitchen operations. This study presents their technology and operational strategies, discusses the resulting impacts on energy use and GHG emissions, and outlines a pathway through which other foodservice companies can realize low-carbon futures. This paper showcases opportunities for achieving decarbonization in commercial spaces and illustrates how to adapt as new ordinances and reach-codes with decarbonization goals go into effect in numerous localities. This paper also demonstrates how to apply DOE's Low Carbon Technology Strategies for Kitchens guidance to achieve significant GHG reductions in one of the most carbon-intensive space types in U.S commercial buildings.

Introduction

Commercial kitchens are notorious for their energy intensity, consuming approximately three times more energy per area than the average commercial building. According to the Commercial Buildings Energy Consumption Survey (CBECS), foodservice takes up approximately two percent of total commercial floor space, but accounts for around six percent of primary energy consumption, resulting in one of the highest energy uses per square foot segments of the commercial sector (CBECS 2016). This high energy intensity in the foodservice sector presents a significant opportunity for improving energy efficiency and reducing GHG emissions.

There is an organic shift happening in the foodservice sector as more operators recognize the need to transition to more environmentally friendly foodservice preparation, while concurrently state and local mandates and reach-codes for building electrification are becoming more prevalent throughout the country. Several states and cities across the country are

aggressively implementing plans to reduce their emissions and achieve ambitious energy and emissions reduction targets for commercial buildings. These plans highlight building electrification and infrastructure as key steps in meeting these targets. This trend towards electrification appears to be steadily increasing and now is an optimal time to leverage that momentum in foodservice as manufacturers are simultaneously following sector trends and producing more innovative technologies and products for commercial kitchens that can reduce carbon emissions.

Many foodservice operators are concerned electrification may adversely affect their bottom lines and product preparations; but electrification, when done strategically and collaboratively, can potentially decrease energy costs. Additional hesitation is based on concerns that certain cooked food products need natural gas as a heat source to maintain product quality and consistency—however, introducing alternative, more energy-efficient equipment during the early stages of culinary education could viably influence current and future generations of foodservice professionals to think beyond the tradition of gas cooking.

This analysis focuses on strategies for electrifying and redesigning America’s commercial kitchens by first exploring the impact of state and local codes, presenting relevant case studies, and delving into useful resources to support the transition to a decarbonized foodservice sector.

Impact of State and Local Codes

States, cities, and other local governments have been initiating mandates to address decarbonization goals. Similarly, energy utilities throughout the United States have also committed to decarbonization in various building types, including commercial kitchens. Cities and counties across the state of California and beyond have initiated mandates requiring new buildings to be all-electric or electrification-ready for mixed-fuel buildings (Gough 2021).

Figure 1 depicts states that have clean electricity mandates and utilities with decarbonization goals throughout the U.S. These goals demonstrate the growing interest nationwide in carbon footprint reductions, and this trend is expected to continue as more states enact legislation for clean energy or carbon reduction goals.

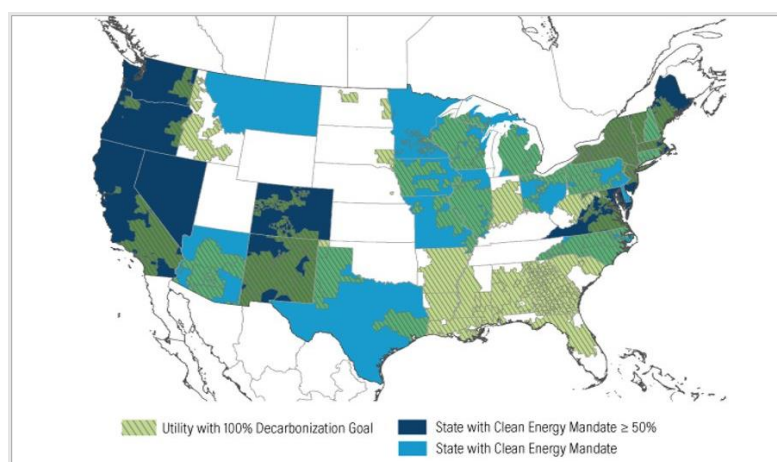


Figure 1. U.S. states with clean electricity mandates and utilities with decarbonization goals, 2021. Source: L. Bird and T. Clevenger, World Resources Institute 2021.

However, many of the state and local codes, standards, and laws—which are expected to go into effect in coming years, if not sooner— include exemptions for gas cooking in restaurants and other commercial foodservice kitchens. For example, Santa Cruz requires “all electric new construction with exemptions for projects that are deemed to be in the public interest and for restaurant cooking” (Gough 2021). These exemptions are made specifically for gas-fueled cooking equipment largely due to the complexities of the power demand for some types of commercial cooking equipment and the electric infrastructure required to effectively meet the demand.

Utilities, states, and municipalities are increasingly exploring a strategy of beneficial electrification. Because electrification will increase electric load and capacity needs, it is important to mitigate those increases by improving the energy efficiency of buildings, industry, and transportation and to ensure that the replacement electric technologies are energy efficient. It is important to consider the impacts of these codes to the operators—from the initial acquisition costs for equipment through the post-implementation operating costs. As a result, the growth in decarbonization-focused local codes can be viewed as both a barrier and opportunity across the foodservice sector.

Strategies for Decarbonization

Carbon emission reductions in the commercial kitchen space can be achieved through the implementation of various strategies ranging from kitchen design to behavioral and operational modifications. Identifying opportunities for replacing and upgrading to highly energy-efficient equipment will support the shift to a more environmentally friendly kitchen operation and help organizations meet decarbonization goals.

Equipment Solutions and Design Techniques

Market transformation toward a more energy-efficient commercial kitchen has been on the rise for years, and through the advancements in technologies and equipment designs, commercial kitchens are producing fewer carbon emissions than before. While federal and utility sponsored programs promote energy-efficient equipment because of their environmental benefit, a key driver for the transition to more advanced equipment in terms of energy and water efficiency is the associated operating cost savings. Though the initial acquisition cost may be set at a premium, detailed cost analysis of the energy savings over the course of varying periods of time demonstrates that high energy-efficient cooking equipment units typically offer a full return on investment in addition to further energy savings.

Incentives offered by utilities can offset the burden of higher initial unit costs, further motivating operators to invest in high energy-efficient cooking equipment. Figure 2 illustrates the energy efficiency levels of conventional, baseline gas and electric cooking equipment compared to high energy-efficient equipment counterparts, with minimum efficiency thresholds (expressed in percentages) that equipment needs to meet to become eligible for the U.S. Environmental Protection Agency (EPA) ENERGY STAR[®] certification and/or as part of the California Energy Wise and other utility-sponsored programs. The figure illustrates how fuel-switching can further help achieve carbon emission reduction through greater energy efficiency of the equipment, assuming clean grid source power generation.

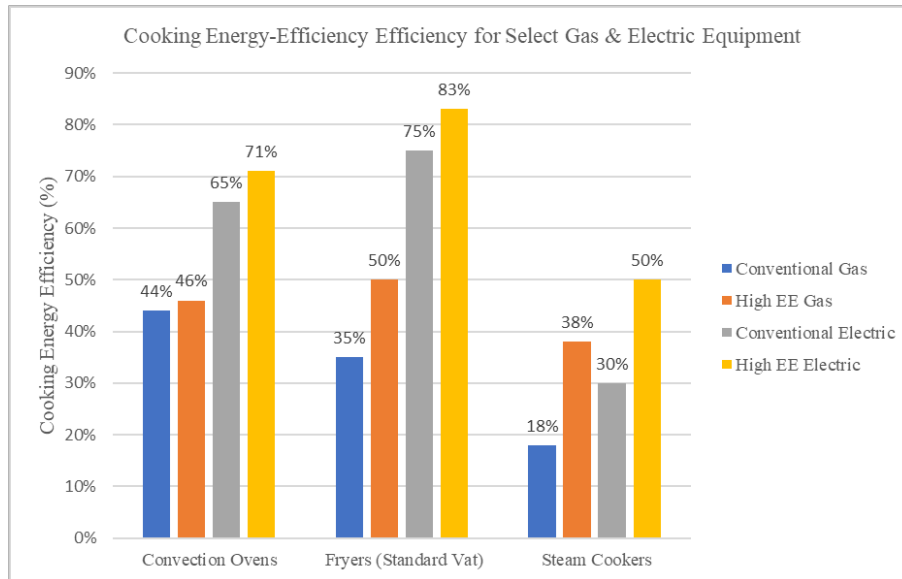


Figure 2. Cooking energy efficiency for select gas and electric equipment. *Source:* EPA 2021.

As the trend toward electrification continues, the demand on the electric load will increase. Installation of high energy-efficient equipment plays a role in offsetting the inevitable growth in electric load demand. Fortunately, significant energy savings and reduced carbon emissions in the kitchen can be obtained simply by investing in high energy-efficient equipment and/or shifting to a different equipment type. Combination ovens, which are inherently more energy-efficient than convection ovens or rotisseries, are commonly used as a replacement primarily due to their increased energy efficiency, versatility, and space savings. Though not every scenario may have the infrastructure to power an all-electric kitchen, the opportunity exists to support decarbonization goals by upgrading to more energy-efficient options. Table 1 lists examples from a replacement field study project conducted in California, which found the greatest savings—68 percent energy savings—came from replacing a rotisserie oven with a large combination oven (Livchak 2017).

Table 1. Equipment replacement field study and resulting energy savings

Site	Baseline Appliance	Baseline Energy	Replacement Appliance	Replacement Energy	Energy Savings
Airline Catering	Convection Oven	4.2 therms/day	Doublestack 6 full Pan Combi	2 therms/day (est.)	2 therms/day (est.)
Restaurant/Bar (Werewolf)	Convection Oven	3.5 therms/day	10 half Pan Combi	1.7 therms/day	1.8 therms/day
Grocery Store	Rotisserie	7.8 therms/day	10 full Pan Combi	2.5 therms/day	5.3 therms/day

Source: D. Livchak 2017.

Investing in ENERGY STAR certified commercial equipment is a simple strategy for improving energy efficiency and reducing utility costs, which help achieves decarbonization goals. Transitioning to energy-efficient cooking equipment is a highly effective path for diminishing carbon emissions in a commercial kitchen. The cooking energy efficiency of a piece

of equipment can vary based on design and technologies. According to the EPA, ENERGY STAR fryers are up to 14 percent and 35 percent more energy-efficient than non-ENERGY STAR models for standard vat and large vat fryers, respectively (EPA 2018b). Comparing sealed cavity ENERGY STAR steamers to open-system, non-ENERGY STAR steamers, show a 60 percent reduction in energy consumption, and combination ovens are as much as 30 percent more energy-efficient compared to conventional models (EPA 2018b).

Even beyond the scope of ENERGY STAR labels, there are other technologies and equipment solutions available that consume less energy and emit fewer carbon emissions than their conventional counterparts. One of the more energy-intensive types of cooking equipment often found in restaurants and kitchens is gas underfired broilers. These are commonly used to cook proteins and vegetables at an elevated temperature, typically between 500-600°F, with much of that excess heat spilling into the kitchen and resulting in higher ventilation exhaust rates (Livchak 2017). Unlike efficient griddles, broilers are non-thermostatically controlled and can end up consuming more than twice the energy of a standard commercial griddle. Though the gas burners are typically turned off during closed hours, there is little manual control to reduce the power to the burner during hours of operation. This results in a consistent high-heat and emissions output over extended periods of time. More advanced broilers employ infrared (IR) burners that offer a more uniform cooking surface temperature, resulting in a lower input rate. Radiant burners typically have an intermediate surface, such as a ceramic element or metal cover, which is heated to high temperatures and the radiant heat is more efficiently transferred to the grill surface than radiant heat exchange between the relatively low emissivity of gas flame to the grill surface. The knobs on these types of broilers control the heat generated for each section of the broiler, with individual burners typically positioned 6 inches apart from one another (Livchak 2017). This allows operators to reduce the number of burners during slow periods of operation or extended periods of non-use, minimizing unnecessary wasted energy and carbon emissions.

The broiler performance profile in Figure 3 depicts two underfired broilers over a 24-hour period. The baseline broiler was replaced by a more efficient IR-burner broiler resulting in reduced input rate (Livchak 2017). Due to the more effective and uniform temperature consistency, the IR-burner model used less energy and yielded fewer carbon emissions.

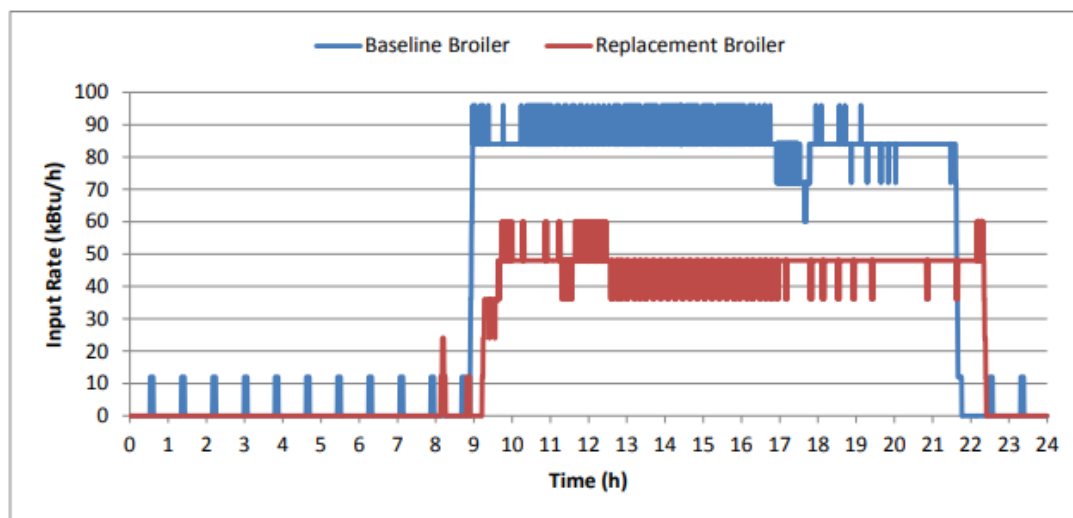


Figure 3. Broiler replacement typical daily energy profile. Source: D. Livchak 2017.

Kitchen Layout: Equipment Consolidation and Ventilation Considerations

Designing a more condensed cookline with a sophisticated equipment schedule can reduce a kitchen's energy consumption without impeding throughput. Versatile food preparation and cooking equipment, such as combination ovens and rapid-cook ovens, can consolidate valuable real estate in the kitchen space, while saving energy and offsetting carbon emissions.

A thoughtful kitchen layout can provide additional energy and carbon savings through reduced ventilation needs. For instance, positioning heavy-duty equipment in the center of the cookline maximizes the ventilation hood's effectiveness without requiring higher ventilation rates. Furthermore, locating double-stacked ovens or steamers at the end of the hood can provide a plume control effect, guaranteeing the cooking effluent and heat that necessitate is removed from the space. Adding partial side panels or end panels to cooking appliances maximizes hood overhang and can have a similar effect. These strategies can also improve indoor air quality through improved ventilation.

Fuel-Switching and Mixed-Fuel Use

The transition from gas-fueled to electric equipment is one of the more straightforward approaches to mitigate emissions in the commercial kitchen. An estimated 80 percent of all cooking equipment in commercial kitchens operates on natural gas, which offers opportunities for switching fuels to cleaner electric alternatives (Electric Power Research Institute 2018), provided the building receives electricity from a predominantly renewable-powered grid. Furthermore, data show that gas equipment simply is not as efficient as electric equipment. The efficiency for gas commercial cooking equipment is estimated to range between 25-50 percent, while electric commercial cooking equipment typically ranges from 60-90 percent (Electric Power Research Institute 2020). Variation in efficiency depends on employment of different technologies, the type of equipment, and equipment design.

Based on the significant potential for carbon emissions reduction via fuel-switching, a complete transition away from gas as a cooking fuel source may seem justifiable. However, in some circumstances, it is not currently the most viable option. There are several considerations for end users, including: economic viability, infrastructure limitations, menu impacts, practicality, and education factors. It is also important to note that there are gradual approaches for fuel-switching that, depending on case-by-case circumstances, can allow for an eventual transition to an all-electric kitchen that would achieve carbon neutrality.

Additional considerations to be made when considering fuel switching is relative GHG emissions of natural gas and electricity. In the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 189.1-2020, the natural gas GHG emission factor (including upstream emissions and methane leakage) is 681 lbs. CO₂e/MWh. Depending on the dominant fuel source of the grid, electricity emission factors range from 540 lbs. CO₂e/MWh in hydropower-dominant Upstate New York (NYUP), to 2,337 lbs. CO₂e/MWh in the coal-dominant region of East Michigan (MROE), and 1,421 lbs. CO₂e/MWh in natural gas-dominant Mississippi Valley (SRMV) region (ASHRAE 2020). While electrifying kitchens today in certain parts of the country would result in carbon emission reductions, many other regions would see an overall increase in emissions due to an increase in electricity produced using fossil fuels. In the latter regions, a more gradual electrification shift would be necessary to minimize GHG emissions. Until electricity generation is largely derived from renewable sources, a mixed-fuel source commercial kitchen with a high-efficiency cookline could achieve the least

amount of GHG emissions from cooking compared to an all-electric kitchen that is powered predominantly by non-renewable electricity.

Regional electricity generation fuel mix is the primary factor when considering a gradual electrification shift. Figure 4 provides annual per unit CO₂e values for natural gas and electric models of three common pieces of kitchen equipment (convection ovens, fryers, steamers) in regions with high, medium, and low carbon emission factors. This comparison shows that relative GHG emissions between natural gas and electric models are independent of equipment type. Gradual electrification should follow the progression of regional fuel mix as more renewables are integrated.

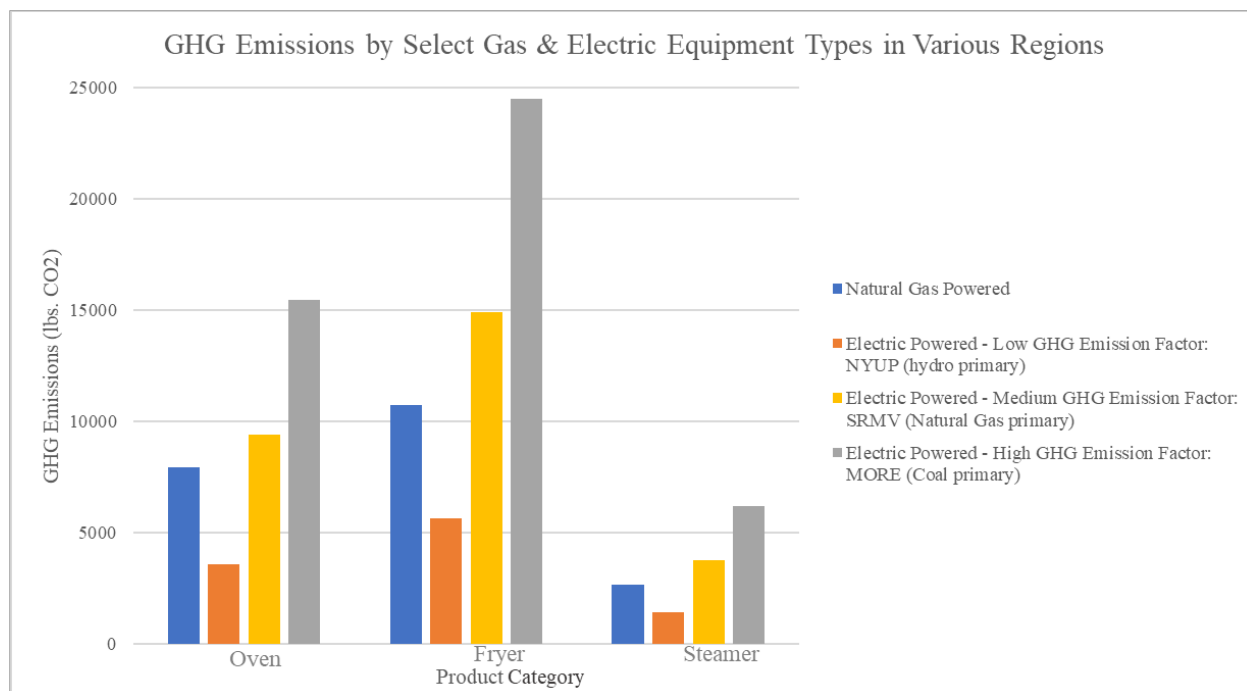


Figure 4. Annual GHG emissions per equipment type based on different regions with varying emission factors. Source CTF 2022, ASHRAE 2020.

Product availability. The opportunity for fuel-switching within the commercial kitchen is not hindered by product offerings. In fact, most cooking equipment that is gas-powered has electric alternatives available, including: cooktops and ranges; convection, combination, rapid cook, rack, and deck ovens; flat top griddles; fryers; woks, tilt skillets, and soup wells; and well warmers. For reference, these equipment products are defined in the American Society for Testing and Materials (ASTM) and/or NSF terminology and nomenclature specifications (ASTM International 2022, NSF/ANSI 2019).

The use of woks in commercial kitchens is one area, for example, where there is strong potential for fuel-switching. Table 2 illustrates this potential for energy savings and associated carbon reduction when switching from a gas to induction wok.

Table 2. Wok production comparison

Rated Input	100,000 Btu/h Gas Wok	5 kW Induction Wok
Efficiency (%)	19%	84%
Production Capacity (lb./hr.)	124 lb./hr.	117 lb./hr.

Source: R. Young, Frontier Energy, presentation, April 9, 2020.

Additional benefits of fuel-switching. The Induction Technology Center (Frontier Energy 2022) highlights additional benefits associated with the use of induction cooking equipment—such as faster heat up times, improved kitchen comfort, ease of clean-up, no combustion byproducts, and decreased risk of fire. Though induction cooktops have a low market share in the U.S. with an estimated 6.6 percent in dollar sales of all commercial ranges sold in 2017, the North American Association of Food Equipment Manufacturers’ (NAFEM) report suggests steady growth of induction cooktops in the U.S. market (NAFEM 2018).

Furthermore, fuel-switching can improve indoor air quality. According to the EPA, Americans spend an average of 90 percent of their time indoors and that indoor air quality is often considerably worse than outdoor air quality (EPA 2018a). Since gas stoves can substantially increase the risk of elevated CO levels indoors, fuel-switching within commercial kitchens (i.e., replacing a gas range with an induction unit) can provide a healthier and safer indoor environment for staff, vendors, and customers of foodservice operations (William J. Worthen Foundation 2022).

Barriers to fuel-switching. Fuel-switching may be as much of a barrier as an opportunity. Gas-bans have met opposition from many states in the U.S.; almost as many of those that support the notion object it for various and justifiable reasons, primarily due to the economic impact. Figure 5 identifies the states in favor of the ban of natural gas and those opposed.

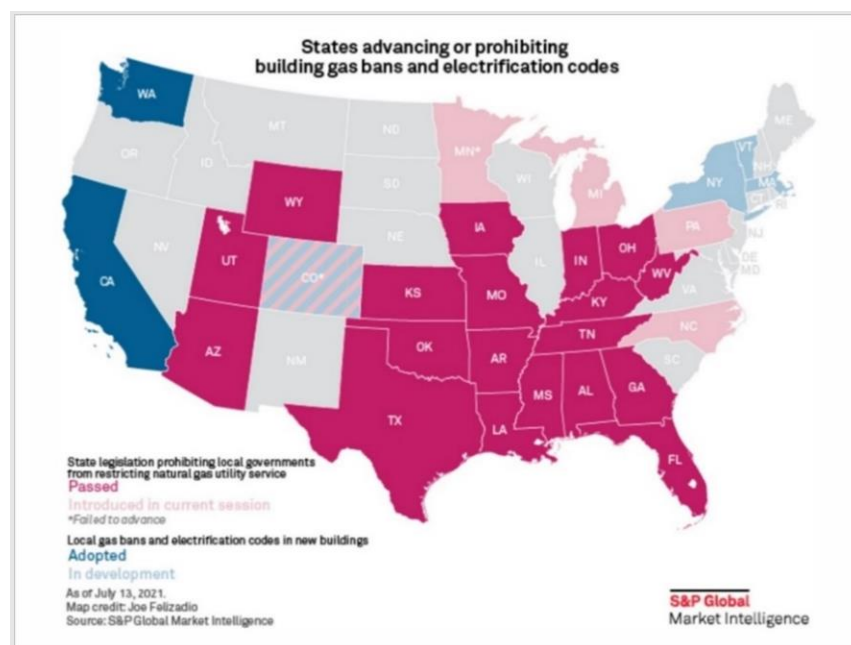


Figure 5. States advancing or prohibiting building gas bans or electrification codes.
Source: T. DiChristopher 2021.

There is a split in the division of for and against swept sides with the states of California and Washington supportive of all commercial building electrification. Speculative forecasting suggests that this may shift over the coming years and decades, but at present most states that have taken a stance oppose restrictions on all electrification in commercial buildings.

Maintenance and Behavioral Changes

Beyond equipment upgrades and fuel-switching, implementing routine equipment maintenance per manufacturer recommendations and adopting behavioral changes are key drivers for achieving decarbonization. These areas offer low-cost opportunities to supplement equipment and design efforts for achieving efficient and effective use of energy.

The adoption of start-up/shut-down schedules can reduce energy waste. There is a misconception that all cooking equipment requires extended periods of time to pre-heat to reach the desired temperature setpoint. However, most normal cooking equipment only requires approximately 20 minutes to pre-heat and most heavy-duty equipment may need an hour (National Restaurant Association 2015). Eliminating extended start-up times also allows the operator to delay activating the kitchen ventilation system. If equipment requires longer-than-normal time to reach temperature, that does not mean the entire cookline needs to be activated simultaneously. Staging your start-up time based on equipment requirements can offset excessive energy consumption.

The process for implementing an equipment start-up/shutdown schedule may be drastically different from one commercial kitchen to another. To be successful in developing an effective energy-saving schedule, foodservice operators must identify target times for the existing operation. Taking stock of the equipment and understanding the pre-heat time can allow for optimization in the kitchen space, and monitoring energy consumption through the integration of an energy management system can further optimize the start-up/shutdown schedule.

The implementation of a regularly scheduled maintenance and cleaning regimen can help mitigate equipment performance degradation and reduce the possibility of premature equipment failure. Aging equipment often results in sacrificed energy performance, and the equipment may not operate as efficiently as when originally commissioned to the cookline. The *ENERGY STAR® Guide for Cafés, Restaurants, and Institutional Kitchens* provides recommended maintenance activities based on equipment type, such as these examples below for automatic commercial ice makers, steam cookers, and griddles, which can help operators offset wasted energy (EPA 2015).

- Automatic Commercial Ice Makers
 - Inspect and clean the coils
 - Adjust the purge water time
 - Reduce idle times
 - Clean the air intake filter
- Steam Cookers
 - Perform regular steam generator maintenance
 - Clean the cabinet
 - Maintain door gaskets

- Griddles
 - Reduce idle time by turning the griddle down or off during periods of slow production
 - Calibrate the griddle controls to operate at the correct temperature
 - Replace missing control knobs

Case Studies

The previous section highlighted effective ways in which to approach high-impact, cost-effective emissions reductions pathways in commercial kitchens. Existing and future codes will likely mandate decarbonization and electrification action, therefore, it is crucial to consider what actions can be taken in the near and long-term to work towards more climate-friendly kitchens. While the foodservice sector can be private when it comes to detailed information-sharing due to competition, there are some public examples of foodservice organizations demonstrating how climate-friendly strategies lead to smarter, healthier, and lower-carbon kitchens. The U.S. Department of Energy's Better Buildings Initiative partners are among the prime, real-world examples that are fundamental in outlining pathways to help others realize low-carbon futures. Certain states are also helpful as examples of the successful implementation of low carbon strategies.

California Examples

In California, state and local mandates have already been established to regulate the foodservice industry and related GHG emissions in addition to the efficiency standards that incentivize electrification. Measures will likely increase in the future; therefore, the need to adapt effectively to new ordinances and incentives to meet decarbonization goals is critical for organizations.

Electrification of foodservice establishments can have public health benefits, particularly since employees and residents in California have been spending more time indoors due to COVID-19 and wildfires. Lamm and Elkind argue that the indoor air quality of the built environment can be beneficial to public health and explain that there are technologies with co-benefits that can improve public health conditions and increase cost savings over time (Lamm and Elkind 2021). Appliances such as stoves and hot water heaters emit a mixture of pollutants, including carbon monoxide, nitrogen dioxide, particulate matter, and formaldehyde, which can cause respiratory illnesses and increased medical expenses, and Lamm and Elkind contend that the replacement of gas-powered technologies or installation of ventilation systems would improve the overall health and wellbeing of employees (Lamm and Elkind 2021). New construction offers one opportunity to introduce technologies such as electric induction stoves, further improving kitchen indoor air quality and reducing pollution. Prioritizing new construction increases the ability to prevent new gas infrastructure quickly and affordably.

These California-based case studies showcase opportunities for capturing energy savings and leveraging utility incentives for commercial kitchen equipment upgrades.

Angelou's Mexican Grill. Angelou's in San Jose, California, for example, took advantage of a utility sponsored rebate program from Pacific Gas and Electric (PG&E), the Step Up and Power Down program, which provided an energy audit that highlighted opportunities to reduce energy waste and fast track equipment updates (PG&E 2022a). As a result, the owners utilized rebates to

replace their inefficient refrigerator, cooking equipment, ice machine, and freezer with high-performance ENERGY STAR models. In addition to replacing aging equipment, the restaurant owners installed bathroom occupancy sensors and habituated behavioral practices such as tracking ongoing daily energy usage and adhering to a startup and shut down equipment process. Angelou's Mexican Grill plans to further their energy savings projects in the future after enjoying savings from these strategies.

DoubleTree Hotel. The DoubleTree in Pleasanton, California also took advantage of a utility-sponsored rebate of approximately \$7,000 to make equipment upgrades to their energy-intensive kitchen operations which offered significant savings, improving expensive utility bills (PG&E 2022b). The full-service hotel kitchen serves needs such as catering, room service, and restaurant orders. After a site assessment by PG&E, three boiler-based steamers were identified as inefficient due to constant repairs, age, and the associated high energy and water usage. DoubleTree replaced the steamers with one electric steamer, one energy-efficient gas steamer, and one energy-efficient combination oven. The prior steamers utilized over half the hotel's electric load and their replacement resulted in approximately 14,500 kWh and 4,800 therms in annual energy savings for the hotel. (PG&E 2022b).

Better Buildings Partner Examples

Sustainable design techniques are crucial to consider as the carbon footprint of buildings with commercial kitchens increases when gas infrastructure is involved. Even in multi-use buildings with one commercial gas kitchen, the entire building will require full gas distribution infrastructure to accommodate (Lamm and Elkind 2021), demonstrating the impact that commercial kitchens have on building emissions.

The Wendy's Company. For example, The Wendy's Company not only invests in high-energy efficiency alternatives in stores across the country, but also realizes the importance of sustainable design. The company utilizes a "Smart Family of Designs" concept which outfits kitchens with energy-efficient measures such as LED lighting and ENERGY STAR certified equipment (Better Buildings Initiative 2018). These kitchens promote significant savings and decrease carbon footprints with the installation of energy-efficient equipment where possible such as fryers, high-efficiency HVAC systems, refrigerators, and ice cube compressors. Actions such as updating to LED lighting are sometimes more expeditiously installed opposed to other more costly decarbonization measures. Wendy's employs another crucial strategy in addition to investing in high-energy-efficient alternatives—education. The Wendy's Company's energy team provides support to franchisees by providing guidance on energy data gathering and tracking processes and emphasizes its importance in understanding the cost benefit analysis of energy upgrades (Better Buildings Initiative 2016a). The support from the company's energy team and external vendors eliminates barriers that franchise operators face and further bolsters the company's decarbonization efforts. This relationship, in turn, helps the company's energy team better understand the unique energy management needs of franchise operators situated in specific localities. An additional benefit of this educational support system is the ability to benchmark facility energy performances to compare with peers and further quantify the positive impacts of subsequent energy efficiency investments. Building operators can see real return on their investments and help their bottom line as they reduce operational costs. Finally, Wendy's

celebrates franchisees' successes as they achieve goals in energy reduction and reduce GHG emissions spurring further investment in low-carbon kitchens to receive recognition.

Starbucks Coffee Company. Starbucks is another Better Buildings foodservice partner working towards more energy-efficient operations. Since energy usage accounts for more than 80 percent of the company's carbon footprint, targeted action towards energy reduction has a significant impact. Starbucks has set a goal to source 100 percent renewable energy for their global store operations in addition to offices and supply chain operations. With this goal, Starbucks established its Greener Stores Framework aimed at reducing carbon emissions, waste, and water usage by 50 percent in 2030. To meet the organization's goals, the Greener Stores Framework prioritizes energy efficiency technologies, investment in renewable energy, and sustainable design among other strategies.

Performance-based standards inform the design process to extend store lives and meet current or future ordinances. One crucial design component in Starbucks' energy conservation goal is the installation of energy management systems (EMS) as a standard. Prior to this standard, HVAC controls were operated manually or set by HVAC service providers (Better Buildings Initiative 2016a). This led to inconsistencies in heating and cooling, increased maintenance needs, and related costs. Once EMS systems were rolled out, remote control and equipment monitoring became possible to optimize space-conditioning and lighting. EMS reports offer the ability to check equipment status, receive performance alerts, and troubleshoot through ease of access. Starbucks also realizes the importance of education and trains staff on EMS functions. Outreach is an important strategy because operator behavior and poor maintenance contribute to excessive electricity usage and, therefore, are fundamental opportunities to address energy usage (Mudie, Essay, Grandison, and Felgate 2016). Overall, the Greener Store Framework results in up to 30 percent more energy efficient operations, which leads to more resilient stores that can respond better to extreme weather, offer improved consumer and employee experience, and positively improve comfort and capacity.

Resources for the Foodservice Sector

Researchers at DOE national labs created a *Low Carbon Technology Strategies Toolkit* for ten commercial building types (DOE 2021b). These documents were supplemented by a *Low Carbon Technology Strategies for Kitchens* resource, which highlights "simple," "intermediate," and "advanced" strategies for equipment, ventilation, refrigeration, and water heating technology categories, with simple strategies including those that do not require much upfront cost or labor while advanced strategies include major upgrades (DOE 2021a). This resource's purpose is to aid existing building owners and operators in planning retrofit and operation strategies to achieve carbon reductions.

Low-energy guidance for new construction can be found in the *Advanced Energy Design Guides* from the ASHRAE. These documents offer designers and contractors the tools needed for achieving zero energy buildings, 50 percent energy reductions compared to ASHRAE 90.1-2004 buildings, and 30 percent reductions compared to ASHRAE 90.1-1999 buildings (ASHRAE 2022). While this guidance focuses on low-energy strategies, the recommendations from the design guides will lead to improved building energy efficiency, which is an integral step to achieve low- or zero-carbon buildings. The documents include guidance for whole building energy reductions. Those focusing on building types that typically include a kitchen contain a detailed section for achieving energy-efficient kitchens.

Educational resources and practice or design guides like the ones mentioned above offer foundational guidance necessary for foodservice industry professionals to make the shift towards all-electric kitchens to support their organizational decarbonization goals. New decarbonization-focused resources for the foodservice sector continue to be developed, such as the recently published, comprehensive practice guide, *The Building Decarbonization Practice Guide: A Zero Carbon Future for the Built Environment*, included one volume dedicated entirely to all-electric kitchens, both residential and commercial (William J. Worthen Foundation 2022).

Conclusion: Future Trends for Commercial Kitchens

Changes are already underway in the foodservice sector as more evidence indicates that gas stoves and other gas-fueled equipment may be more damaging to the environment than previously understood. Major foodservice equipment manufacturers are recognizing the need to shift to electric equipment over natural gas. Manufacturers and chefs are discussing the common misconception that electric cooking does not always offer the same results. Middleby Corporation is one of the U.S.'s largest equipment manufacturer groups that is working to debunk that myth by shifting its equipment focus to electric, noting that electric cooking equipment can achieve the same results as gas-powered equipment (Middleby 2022). The organization cites recent research that gas-powered cooking equipment emits 6.8 million tons of CO₂ and gas stoves emit 2.6 million tons of methane each year (Lebel, Finnegan, Ouyang, and Jackson 2022).

Utilities have also introduced fuel-switching programs, recognizing the benefit of improved safety, increased comfort, reduced cost of space conditioning with electric equipment that generates less heat, and additional energy savings from downsizing equipment and equipment schedules that allow for reduced exhaust fan speed demand. For example, the Sacramento Municipal Utility District (SMUD) has introduced Go Electric Food Service incentives, which offer commercial kitchen businesses the opportunity to transition from gas-fired systems (i.e., range tops) to electric induction cooktops. The program also offers incentives for electrical infrastructure improvements (SMUD 2022). Southern California Edison (SCE), as well as other utilities, have recently added induction cooktops as part of their energy efficiency lending programs to allow commercial customers to pilot the technology in their own facilities before making the ultimate decision to replace gas ranges or woks with induction alternatives (Southern California Edison 2021). SCE further explains, "With the help of partnerships of induction manufacturers, the SCE Induction Lending Program has been a success for both residential and commercial customers. The goal of the program was to bring education, awareness, and demonstration of the induction technology. Participation has increased over the last year with many customers providing positive feedback. We are looking forward to additional success & awareness with future rebates and ENERGY STAR Commercial Electric Cooktop Specification to help bring the technology to the forefront of electric cooking." (A. Saldivar, senior engineer, Southern California Edison, pers. comm., June 1, 2022).

As an increasing number of restaurants and commercial kitchens adopt strategies for decarbonization, the demand for high-efficiency electric equipment will continue to rise and lead to more operators interested in following suit. Equipment manufacturers, states, utilities, local governments, chefs, and other foodservice industry professionals have demonstrated that a big shift has already begun, yet the trend of decarbonizing the commercial kitchen is still in its infancy stage with a long way to go. As educational resources become more mainstream in the foodservice community and stakeholders become increasingly aware of the critical importance of

carbon reduction, momentum will continue to grow, and the decarbonized commercial kitchen will become a fixed reality across the sector.

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