The Role of Gas-Powered Cooking in Commercial Kitchens and the Potential for Electrification

By

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A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Energy and Resources

in the

Graduate Division

of the

University of California, Berkeley

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Spring 2025

Abstract

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Any restaurant considering electrifying its kitchen must weigh diverse factors such as its capital and operating budgets, its customers' culinary traditions and preferences, and the capabilities of electric induction equipment to produce the flavors and textures desired by customers. All these factors help determine the viability of restaurant electrification on an individual restaurant and society-wide level, and the success of public policies and incentives aiming to scale commercial kitchen electrification hinge on whether they adequately address these and other concerns. Despite the urgency of answering these questions, however, the existing building electrification literature focuses largely on residential electrification.

This work aims to fill these knowledge gaps by launching four separate research projects examining the viability of commercial kitchen electrification. The first project conducted a survey asking 107 people around the San Francisco Bay Area if and how they evaluated restaurant cooking methods when deciding where to eat out and how their beliefs about flame cooking might inform those decisions. Those questions aimed to give restaurants more guidance on customer expectations of electric-powered cooking and whether restaurants risk losing customers if they electrify their kitchens. The second project employed participant observation methods to describe how restaurant staff physically navigated their kitchens and how those physical rhythms might inform the restaurant kitchen's internal culture. That line of inquiry aimed to determine how much staff retraining would be required with kitchen electrification and how much that might increase up-front electrification costs. The third project audited the energy use costs and greenhouse gas emissions of a Sacramento restaurant currently cooking with gas and estimated those costs and emissions under an all-electric scenario. The fourth project conducted several cooking experiments

evaluating whether electric induction cooktops could produce the same flavors and textures commonly desired in specific dishes that are cooked with flame. As part of this fourth project, the co-owner and a staff member of the Sacramento restaurant were also observed using electricity-powered cooking equipment in a test kitchen to gauge how well the electric equipment produced certain dishes.

The second and third research projects produced interesting results showing that restaurants will likely face prohibitively high up-front capital costs when electrifying existing natural gas-powered commercial kitchens. Although kitchen electrification produced substantial yearly energy savings for the Sacramento restaurant, the audit found, making up for high up-front electrification investments through those operating cost savings will take the restaurant a decade or more even when utility-offered electrification infrastructure rebates are factored in. Additionally, the second project found that at least some amount of staff retraining will be required in most restaurants given the quicker cooking time and different heat processes of induction stovetops, further adding to up-front kitchen electrification costs.

The surveys conducted for Part 1 of this work found that the respondents were generally open to patronizing all-electric restaurants although they still largely believed that certain dishes such as grilled meats and vegetables and Chinese stir-fries required flame to be cooked properly. The experiments conducted for Part 4 of this work supported those survey respondent beliefs about the need for flame cooking to prepare certain dishes, especially when using induction woks to properly flash fry meats. These sets of results suggested that customers will accept restaurant electrification for many types of cuisines but that certain types of foods will be difficult to cook on electric induction stovetops to most customers' satisfaction.

This work does not propose or examine any specific kitchen electrification policy initiatives, but it aims to highlight cultural, economic, and culinary considerations that electrification policies should take into account to help scale commercial kitchen electrification. This work also argues that people's mental narratives about food preparation should play a central role in the kitchen electrification debate in addition to economic and culinary concerns. In particular, this work highlights the role that culture, history, social values, and other hallmarks of people's lived experiences play in determining the progress of commercial kitchen electrification. This work argues that such elements must be considered alongside more quantitative measures such as cost and infrastructure in any energy transition initiative as other energy transition efforts such as transportation electrification or fossil fuel industry demobilization also play out against deep-seated regional cultures and traditions. A rich body of theory and research already exists on many of these energy transition topics, especially in the fields

of anthropology and cultural studies, and they can all be leveraged in future work.

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Acknowledgements

I would like to thank my dissertation committee members, Professors Mariane Ferme of the Department of Anthropology at UC Berkeley, and Daniel Kammen and Isha Ray of the Energy and Resources Group, for all their guidance and support. I also send thanks to UC Berkeley Mechanical Engineering Professor Lydia Sohn, who served on my qualifying exam committee, and UC Berkeley Anthropology Professor Christine Hastorf, who talked with me at length about food and culture in and out of class.

I would like to send special thanks to Ranxi Zang, an undergraduate student in my Climate Change Communications course who later helped me review and summarize Chinese-language research into cooking thermodynamics and helped me conduct an electric induction wok cooking experiment for Chapter 4 of this work. Thank you also to Jennifer Short, my aunt, for helping to translate the food preferences survey into Chinese and for assisting with several of the induction wok cooking experiments. Thank you to Willy Lizarraga as well for helping to translate the food preferences survey into Spanish. Thank you to Michelle Vigen Ralston who helped guide me along my energy career journey. And thanks to Michael Colvin, of the Environmental Defense Fund, and Katie Wu, of Common Spark Consulting, who helped me first brainstorm this dissertation topic.

I send my appreciation to Kay Burns, former graduate student advisor at the Energy and Resources Group, who helped me navigate graduate school in my mid-40s. This education has helped me reinvent myself when reinvention was needed, and for that I will be forever grateful.

Finally, I send love and appreciation to UC Berkeley, where I have been enrolled as an undergraduate and graduate student for 12 years starting in the early-1990s. Its classrooms, libraries, student lounges, hilly pathways, and brilliant people will always be a part of me.

Introduction

For the past two decades, California has regularly surpassed its own ambitious decarbonization targets by reducing its reliance on coal- and natural gas-powered electricity generation and transitioning to solar, wind, and other renewable sources. This has been an unqualified success story and an inspiration for other forward-thinking governments striving to meet the unprecedented challenges posed by climate change. California's progress, however, has produced a subsequent challenge. As more zero-carbon electricity powers California's grid, natural gas, or methane, used to generate heat in buildings is growing as a percentage of the state's total greenhouse gas emissions. Methane is burned in large part in California's cities to produce heat for cooking, space and water conditioning, as well as to generate the intense heat required in industrial processes such as steel and petrochemical production. In some cases, alternatives to methane combustion such as electricity-powered industrial furnaces have proven technologically infeasible given the extremely high temperatures needed in most of those processes. In other cases, financial barriers and end-user resistance have slowed adoption of other alternatives to methane combustion such as heat pump water and space heaters and electric induction stovetops. As a result, those heating processes still largely depend on the burning of fossil fuels.

The results for many California cities is that methane use and emissions have stayed stubbornly constant even as carbon dioxide emissions have fallen due to a cleaner electricity grid. In San Francisco, for example, commercial and residential building emissions made up of 44 percent of the city's total greenhouse gas emissions in 2022, with 95 percent of residential building emissions and 72 percent of commercial building emissions stemming from combusting natural gas to generate heat. (San Francisco Department of the Environment, n.d.)

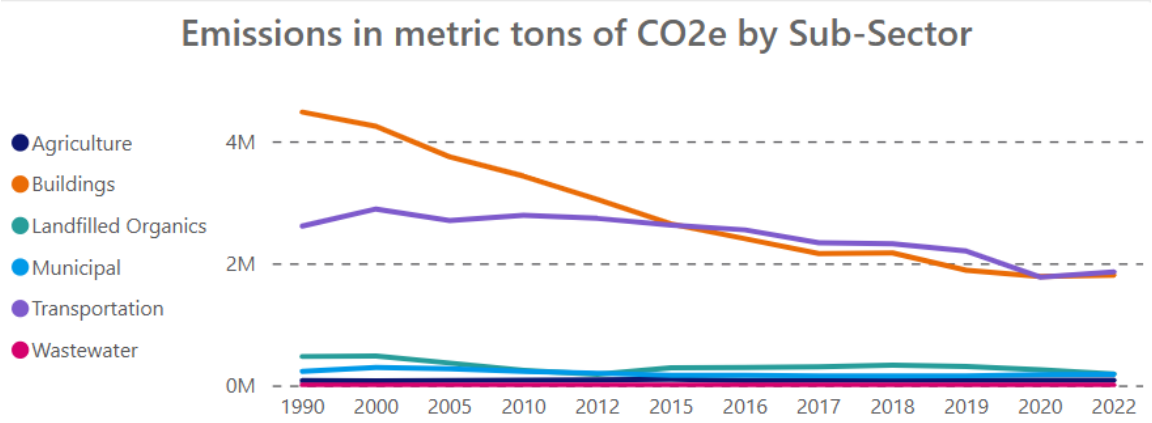


Figure 1: CO2-equivalent emissions related to buildings in San Francisco declined since the 1990s but have stopped falling since 2019, largely due to methane use in buildings. (Source: City of San Francisco)

Statewide, methane is the second largest type of carbon dioxide-equivalent emitted, at 10.5 percent of total statewide emissions in 2020. (California Air Resources Board [CARB], n.d.) While much of those emissions come from the agricultural sector, principally from livestock enteric fermentation and manure management, millions of metric tonnes of methane every year still emanate from producing space and water heat and cooking food in apartments, houses, restaurants, and other buildings. (CARB, n.d.)

Local Action to Phase Out Methane Use

In that climate context, dozens of California jurisdictions passed ordinances limiting methane use in buildings (See Figure 2). The local gas ban movement got underway in 2019, when the city of Berkeley became the first in the United States to prohibit the installation of methane infrastructure in all new construction. Seventy-three other cities and counties in California alone, including the cities of Los Angeles and San Francisco, followed suit and passed legislation banning methane infrastructure in new buildings or requiring buildings be constructed with electrical infrastructure that can accommodate electric heat pump water and space heaters and induction stoves.



Figure 2: Cities in California that have adopted legislation banning natural gas infrastructure in new buildings or requiring buildings be built to be "electrification-ready." (Sierra Club, n.d.)

As the gas ban ordinance wave grew, local governments across the country passed their own versions of such ordinances, and cities such as San Diego and San Francisco even began targeting gas infrastructure in existing buildings - an ambitious move especially in cities such as San Francisco with an aging housing stock.

That legislative momentum came to a halt, however, in April 2023 when the U.S. Court of Appeals of the 9th Circuit ruled that the city of Berkeley had preempted federal appliance efficiency standards with its gas ban by restricting the supply of methane to appliances such as water heaters, space heaters, and stoves. (California Restaurant Association, 2023) Only the federal government could restrict the supply of methane to appliances, the court ruled, effectively killing the leading legislative tool used by U.S. cities up until then to curtail building-based methane consumption.

As the plaintiff, the California Restaurant Association based its argument on the alleged damage such gas bans would inflict on restaurants. The association argued that restaurants that depend on gas cooking for their economic survival and gas bans impose a disproportionate cost on city businesses and residents. (California Restaurant Association, 2019) The lawsuit stated:

Restaurants rely on natural gas for such things as food preparation and heating space and water, and even providing backup power during electrical outages. Many of these restaurants rely on gas for cooking particular types of food, whether it be flame-seared meats, charred vegetables, or the use of intense heat from a flame under a wok. Indeed, restaurants specializing in international foods so prized in the Bay Area will be unable to prepare many of their specialties without natural gas. Many chefs are trained using natural gas stoves, and losing natural gas will slow down the process of cooking, reduce a chef's control over the amount and intensity of heat, and affect the manner and flavor of food preparation. … Restaurant owners and employees as well as restaurant customers also will be denied the use of gas appliances to prepare food, heat their homes or water, or use gas fireplaces in newly constructed buildings. And a shift to "all electric" also will impose greater costs on Berkeley businesses and consumers, in the midst of an affordable housing crisis.

(California Restaurant Association, 2019)

This passage provides the problem statement of this work. While the restaurant association does not represent all restaurants, its complaint brought to the spotlight real-world considerations that inform whether a restaurant can realistically switch from natural gas-powered to electric-powered cooking. This work accepts the challenge of the statement, takes its concerns seriously, and reality checks them using diverse academic methods and disciplines. Given the outsized role commercial kitchen electrification has played in the larger building decarbonization battle, this work aims to shine light on this consequential issue and follow the results wherever they lead.

This focus of commercial building electrification contributes a largely missing component in current building decarbonization research. Since restaurants exist to turn a profit, this research necessarily focuses on kitchen electrification as a business proposition and attempts to inform the discussion of how electrification impacts for-profit businesses such as restaurants. That is a fundamental difference between residential and commercial kitchen electrification. A residential kitchen is not expected to turn a profit or even pay for itself. A restaurant kitchen is at heart an economic engine; any disruption to that operation could impact costs, employee work practices, the restaurant's ability to prepare certain foods, or the restaurant's public branding. From this perspective, this research aims to produce a kind of multi-disciplinary feasibility analysis for commercial kitchen electrification.

Conceptual Framework

For multiple reasons, kitchen electrification has emerged as arguably the most contentious component of the building decarbonization push, with opposition to electric stove mandates crossing political lines, from coastal, politically liberal foodies to cultural conservatives already suspicious of climate science and clean energy mandates. While requirements to replace gas-powered furnaces and water heaters have mainly raised concerns about the cost of appliances and electrical system upgrades, those mandates have not sparked the type of visceral political and commercial opposition that has risen up against proposed gas stove bans. (Hao, 2023) Against this backdrop, commercial kitchen electrification presents a unique set of questions that demand new research. The methods and theoretical approaches of this research examine this kitchen electrification issue through three conceptual lenses, each of which illuminates a different energy transition challenge.

1. Culture and Values Around Food

First, this work examines the cultural values and meanings around food and food preparation as revealed in theoretical and ethnographic work. This anthropological approach addresses the personal values that culinary traditions have embodied for people and societies and the values of modernity and authenticity that food can signify. This approach draws on diverse literature such as the structuralism framework developed by Mary Douglas and ethnographic fieldwork such as observations of kitchens of immigrant households conducted by anthropologist Lydia Marte. This framework informs the work's concerns with the cultural and moral dynamics at play with any changes to long-stranding culinary practices and traditions, and how those dynamics contribute to the debate about kitchen electrification. This work argues that flame cooking may be *the* culinary practice with the most symbolic and cultural weight for its practitioners, and *the* unique innovation that long ago distinguished humans from other species, as English anthropologist and primatologist Richard Wrangham wrote in his book *Catching Fire*. (Wrangham, 2009) This work concludes that any effective kitchen electrification policy must take these cultural concerns seriously and adapt their design and application to specific cultural environments.

This conceptual component is a core consideration for restaurants considering electrifying their kitchens because restaurant owners must ostensibly anticipate the preferences of customers and how they expect their meals to be prepared if they hope to build a loyal clientele. As the saying goes, the customer is always right, and restaurants will serve the specific dishes they think people will want and prepare them in the way they believe customers expect them to be prepared, whether it's grilled, fried, boiled, or baked. At the same time, a customer will expect a certain type of food from a restaurant based on

multiple factors – that customer's cultural background, their personal relationship to the dish, the restaurant's décor, the cost of the dishes, and how specialized the menus are to a particular regional cuisine, among other factors. Food preparation methods are an ingrained part of this system of cultural meanings. For example, restaurants that promote themselves as offering grilled, smoked, or other food prepared with flame are evoking a specific food culture and regime - one that this work suggests crosses ethnic boundaries. At the same time, restaurant owners don't actually know in most cases how their customers prefer their dishes to be cooked so restaurants must try to guess their clientele's preferences.

This work aims to fill that knowledge gap through surveys conducted at farmer's markets and other public gatherings around the San Francisco Bay Area asking specifically how customers choose which restaurants to eat out at, whether cooking method enters into that customer's deliberation, whether flame cooking is an essential part of their expectations about certain foods, and whether they have tried cooking on an induction stovetop before. The survey results are analyzed by gender and ethnicity to capture the food preparation expectations around certain ethnic cuisines. This instrument achieves a large and representative enough sample of respondents to produce valid and useful insights into public opinions about restaurant cooking techniques and how people decide where to eat out.

These results can hopefully offer restaurant owners insights into how customers actually expect certain foods to be prepared and the degree of importance they place on food preparation when they choose where to eat out at. The hope is this research can serve as a reality check on restaurant owner beliefs about customer expectations of certain foods, and in particular whether flame is needed to prepare dishes that meet customer expectations.

2. Culture and Work in Commercial Kitchens

The second conceptual element of this work examines commercial kitchen electrification as an addition or even as a disruption of a system of workplace behaviors defined by experience, tradition, and personal culture. This section is rooted in the "body memory" ideas of theorist Marcel Mauss, who connected physical behaviors and actions to expressions of national and ethnic identity. In his 1978 piece "Techniques of the Body," Mauss theorized that national identity can determine the specific style of diverse activities such as walking, marching, sitting, or even having sex. Mauss writes:

> *The constant adaptation to a physical, mechanical, or chemical aim (e.g. when we drink) is pursued in a series of assembled actions, and assembled for the individual not by himself alone but by all his education, by the whole society to which he belongs, in the place he occupies in it.*

> *Moreover, all these techniques were easily arranged in a system which is common to us, the notion basic to psychologists, particularly [William Halse] Rivers and [Sir Henry] Head, of the symbolic life of the mind; the notion we have of the activity of the consciousness as being all of a system of symbolic assemblages. (Mauss, 1973)*

Similarly, the layout of the restaurant kitchen as well as the culture of a particular restaurant can help determine how kitchen staff move in their workplaces and how they perform basic tasks such as chopping, grilling, and rolling dough. Commercial kitchen staff learn these practices through training and experience, whether passed down explicitly through more senior staff or learned through observation. Then, through daily repetition, those practices become a part of employees' body memories - unconscious expressions of culture and identity similar to how people dress themselves, speak, or eat. (Mauss, 1973) Similarly, sociologist Pierre Bourdieu writes about the importance of what he calls *habitus* in guiding people's behaviors in specific times and places – what he terms "embodied history, internalized as a second nature and so forgotten as history." (Bourdieu, 1980) This research explores the concept of *habitus* in commercial kitchens and how they help determine how people physically move about the kitchen as determined by their training and overall culinary tradition.

This section builds on those body memory and *habitus* concepts by drawing on studies about domestic technology adoption such as Ruth Cowan's seminal book "More Work for Mother" examining the evolution of domestic technology in the United States and how the introduction of innovations such as refrigerators and vacuum cleaners impacted household gender dynamics and even the very concept of work. (Cowan, 1983) In the case of commercial kitchens, the introduction of new technologies such as induction cooktops has the potential to change social dynamics within the kitchen. For example, an innovation that makes a previously time-intensive task less demanding or even replaces the need for human staff to perform it can lower or even erase the status of a staff person specialized in that task. Combining this concept with Mauss' body memory idea, the introduction of new kitchen technologies can also change the physical culture of the kitchen as embodied by all of its staff if the new technology significantly alters the kitchen work flow. Induction cooktops, specifically, heat up pots and pans much more quickly than flame-based cooking in most cases, which can change the rhythm-based work flows of commercial kitchens.

This section aims to describe such body memory impacts by first describing the gas-based kitchen work flow itself. This research employs the standard ethnographic method of participant observation - in this case, of restaurant kitchens around the San Francisco Bay Area - to document how professional cooks balance the many tasks involved in running a commercial

kitchen, and particularly how such cooks incorporate the rhythms of flame-based cooking into their routines. This section connects such observations to the business case for commercial kitchen electrification - namely, whether restaurants will need to invest substantially in retraining employees who have built careers out of cooking and otherwise preparing foods in natural gas-powered restaurants. Such body memory skills are a core part of commercial kitchen expertise, and electrification could require kitchen staff to re-train how they operate in a restaurant kitchen.

3. Capital and Operating Costs of Kitchen Electrification

The underlying reality of this research is that restaurants are businesses, which means any capital and ongoing expenses incurred by electrification must eventually be paid for through revenues earned by the business. Additionally, the successful performance of newly installed electrical stoves and ovens in the restaurant is crucial to its survival, and any delays caused by sub-standard equipment could threaten the business' viability and future. By contrast, the performance of an induction stove in a private home may cause inconvenience and even require additional investment in replacement or repair, but it does not necessarily impact the household's future earning potential and its ability to pay the mortgage and bills.

This difference necessitates a different kind of financial assessment of the costs and benefits of kitchen electrification than that used for residential electrification – one that reflects the less forgiving margins of the restaurant industry and the operational costs of shutting down a kitchen for even a day or two due to equipment repair or replacement. This analysis must examine how kitchen electrification impacts a restaurant's business model and impacts capital and operating costs. This is by definition a type of bottom line-based analysis that is fundamentally different from any residential customer cost-benefit analysis.

This section estimates the estimated up-front and ongoing energy costs as well as greenhouse gas emissions of a Sacramento restaurant participating in this research that is interested in switching from its current natural gas-based cooking technology to a potential all-electric scenario. This section performs an exhaustive financial analysis of the kitchen's current infrastructure and models a similar kitchen using only electric appliances. This section also leverages available state commercial end-use survey data that measures the annual energy usage by electric, gas, and mixed-fuel commercial kitchens in different utility services areas in California.

4. Thermodynamic Differences in Induction Cooking

The final component of the conceptual framework examines the physical transformations that flame and heat cause in meats, vegetables and other

foods. This approach provides a molecular context for the operation of gas versus electric stoves, which can help determine the physical capacities of different cooking methods and connect them to values and theoretical concepts of cuisine. This literature builds on the popular field of food science popularized in works such as Harold McGee's *On food and cooking: the science and lore of the kitchen* and Cook's Illustrated *The Science of Good Cooking* and America's Test Kitchen TV show. This section applies this theoretical framework to the question of whether induction cooking can adequately reproduce the physical transformation of meats, vegetables, and other foods that flame cooking accomplishes as well as produce the corresponding flavor profiles generated by flame cooking. This framework also examines whether any physical transformations in ingredients that can exclusively be produced by flame cooking are non-negotiable elements of certain dishes or whether consumers can reasonably adjust to different textures and flavor profiles produced by induction cooktops. In particular, this section examines whether induction woks can produce the same textures and flavors in seared stir-fries cooked in woks over intense flame - a cooking process often cited by kitchen electrification opponents as infeasible on induction woks.

This section examines possible differences in thermodynamic results with experiments cooking different types of food on a regular electric induction cooktop and in an induction wok and comparing the results to cooking the same foods over flame. The research also focuses on Chinese cooking techniques that require intense flash heat to sear sauces and meats in woks. The results of these cooking experiments aim to demonstrate both the capabilities and the limitations of induction cooktops in producing different types of dishes from diverse culinary traditions. Through in-kitchen tests, this work reality checks certain popular assumptions about the capabilities of electric induction stoves to cook dishes sometimes assumed to only be able to be prepared with natural gas-powered technology.

Taken together, this conceptual framework aims to address the primary factors any restaurant considers, either consciously or unconsciously, when deciding whether to switch to electric induction cooking. These research foci also aim to build off existing residential kitchen electrification literature by applying anthropological, behavioral, economic, and thermodynamic approaches to the unique context of commercial kitchens.

Existing Research Overview

Research on commercial kitchen electrification is scant in the existing academic and policy literature, with most past research focusing on residential electrification and the health impacts of natural gas-powered cooking. This work aims to fill that gap by employing an interdisciplinary approach pioneered

by the Energy and Resources Group at UC Berkeley. Through both quantitative and qualitative methods, and by employing past research from fields such as food anthropology, structuralist cultural theory, and thermodynamic physics, this work intends to contribute to all of these fields as well as fill in diverse knowledge gaps specific to commercial kitchen electrification.

First, this work builds on extensive research already conducted into residential kitchen electrification, which can inform general discussions about energy transitions. Within the Energy and Resources Group, researcher Cristina Crespo Montanes has interviewed residential households about their perceptions of home electrification in the context of growing electricity system unreliability due to climate-induced events. Other research conducted by Yael Nidam at the City and Regional Planning Department at UC Berkeley also uses interviews to examine the effectiveness of subsidies and other assistance programs designed to help residents electrify their homes. The UCLA Fielding School of Public Health and researchers at other institutions have also studied the health impacts of natural gas-powered stove use within residences. (Zhu, 2020) Again, these research streams focus largely on residential customer attitudes and costs with some implications for commercial kitchen electrification.

Research conducted at UC Berkeley and other institutions have also examined the cultural and economic impacts of transitioning from using wood- or dung-burning stoves to stoves powered by liquefied natural gas in rural areas of Africa and Asia. This research explores factors such as the rate of technology adoption by household cooks - mainly women - and whether households stick with new cooking technologies after adopting them. In particular, this research examines how cultural and behavioral dynamics can inform efforts to convert rural households to cleaner-burning domestic technology, and how those households sometimes resist fuel-switching due to emotional, financial, and cultural attachments to the older cooking technology. (Gill-Wiehl & Kammen, 2022)

This research forms parts of a rich body of literature studying domestic technology adoption, including *More Work For Mother*, exploring the gender, racial, and class impacts of wide-scale transitions in domestic technology adoption, whether in rural India or in suburban United States or in northern United Kingdom. This research is often ethnographic in approach, relying on methods such as participant observation, interviews, and surveys. This research field also draws on the burgeoning field of energy storytelling most notably represented by the research collected in the September 2017 edition of the journal Narratives and Storytelling in Energy and Climate Change Research. As the authors write in their intro,

> *This special issue aims to present and cultivate structures for understanding, interpreting, and applying stories within energy and climate change research and policy by presenting a breadth of analytical approaches, and showcasing projects and research that feature stories or their performance in the energy and climate change fields. (Moezzi et al., 2017)*

Similarly, this research explores the narratives of restaurant owners, kitchen staff, and customers in an attempt to illuminate how they think about food preparation and energy use and the ways that culture and tradition can shape those perspectives. This research pays special attention to the role that such experiential factors as tradition, stories, mythologies and cultural values play in transitioning people and businesses from fossil-based to cleaner energy sources. This research in particular advocates for giving such cultural factors as much consideration as more quantitative elements such as cost or infrastructure when considering the feasibility of clean energy transitions.

Finally, this work draws on extensive research into cognition and decision-making and behavioral design strategies often employed by marketers. Those techniques include nudging, or small interventions designed to steer people toward a certain behavior; default choice program design that requires people to opt out of the targeted behavior when signing up for utility and other services; and social practice theory that takes into account social norms when designing programs promoting certain behaviors. This behavioral studies literature serves as important context for the research presented here since this work focuses on the conscious and unconscious considerations that determine whether a restaurant chooses to electrify its kitchen and whether a customer frequents a restaurant using electric induction cooking technology.

While this work does not make any policy recommendations, understanding the diverse factors established in existing literature as well as in this work can help policymakers design incentives, energy rates, and subsidy programs to encourage electric induction technology adoption. This work does not suggest or evaluate specific nudging strategies, but it aims to generate insights that can inform the design of such strategies.

An Interdisciplinary Approach

This work adopts methods and literature from diverse backgrounds to answer research questions that cross disciplinary boundaries while informing multiple lines of inquiry. The necessities of the research questions contemplated by this work have dictated this interdisciplinary approach, as the real-world challenges faced by restaurant owners and policymakers raise questions that require methods such as technoeconomic analysis, participant observation, and surveys about socio-cultural attitudes about food and cooking. To be sure,

borrowing from different fields in one work presents distinct risks - in particular, the potential misuse of a discipline's literature and methods as well as the production of mismatched and unconnected results that fail to cohere into an integrated whole that say anything useful. Before undertaking this interdisciplinary approach, this work sought to meet several criteria addressing these overall concerns.

First, this work aimed to produce research results that complement and inform each other. This work sought to ensure that each chapter's results contributed to a larger understanding cumulatively created by all of the chapters so that the data points did not stay siloed in their own fields. In practice, these research topics arose from interviews and observations conducted at restaurants around California where restaurant owners and chefs discussed the feasibility of electrifying commercial kitchens. Several of these concerns inspired individual chapters employing specific research that could produce tangible results that answered owner questions. For example, surveys about customer preferences regarding food preparation produced data that could then inform restaurant owner understanding of customer expectations and thus electrification's potential impacts on their revenues. Similarly, the in-kitchen tests determining the ability of electric induction- and natural gas-powered cooking to prepare certain dishes helped reality-check attitudes revealed by the survey, and in particular beliefs about the ability of electric induction stoves to prepare grilled meats and vegetables, Chinese stir-fries, and other dishes commonly believed to be uniquely suited to flame cooking. As one more example, the observations made about restaurant kitchen staff working in natural gas-powered kitchens could help determine the extent of training that would be needed to prepare staff for working in all-electric kitchens - again, part of an economic feasibility analysis that all restaurants will need to undergo when deciding whether and how to electrify. Each question led to additional questions, which produced diverse answers that hopefully added nuanced context for results across chapters.

Second, this work aimed to employ the methods and literature of each research field with enough depth so that the results produced significant insights within the context of that field. In other words, each chapter should do more than visit each discipline; it should contribute to that research literature as well by filling gaps in that body of literature. To that end, as noted previously, this work contributes meaningfully to the building electrification literature as a whole by examining these issues in the commercial kitchen context whereas previous literature has focused on residential electrification. This research also contributes to the field of "body memory" studies as described by Mauss by applying that idea to the kitchen workplace and exploring how such body memory informs the rhythm and work flows of commercial kitchens. Mauss' work itself does not apply this concept to the workplace routine, focusing instead on

developmental and social behaviors such as breastfeeding, eating, dancing, and sleeping. (Mauss, 1973) Additionally, the current electrification literature does not employ the "body memory" concept at all, much less to commercial kitchens, especially in the context of kitchen technology innovation.

Hopefully, this work can help expand this type of "body memory" analysis to other social and professional contexts. Finally, this analysis employs participant observation methods to study commercial kitchens as cultural and social systems in themselves, which adds to the anthropology literature examining the values, hierarchies, and social customs, including around cuisine, that order social groups. The study of work as a social system is indeed well-developed and rich, including research examining the impact of new technologies in workplaces. (Heath et al., 2000) This work contributes to that body of literature by examining how workplace social dynamics are shaped by the use of specific cooking technology and how the introduction of a new technology could impact existing social structures and practices in commercial kitchens. This research focus also echoes "More Work For Mother," but this work applies this technology adoption analysis to an environment outside the private home.

A third criteria used to guide this work isn't specific to an interdisciplinary approach but represents a fundamental motivation for conducting this research. This criteria states that the research should be genuinely useful for people and businesses trying to electrify commercial kitchens within their constrained budgets and resources. Additionally, this research should be useful and applicable for policymakers trying to develop kitchen electrification support programs, incentives, or mandates that can help expedite and scale commercial kitchen electrification. In other words, can this research help advance decarbonization efforts on the ground? To answer this question, it is worth noting that all these chapters strive to answer the basic question of "What are the financial and logistical costs for restaurants switching from natural gas-powered to electric induction technology?" The four research streams detailed in this work are designed to answer that question in an integrated way, and the interdisciplinary nature of this work reflects the natural complexity of a fast-evolving real-life dilemma such as commercial kitchen electrification.

Building on existing residential kitchen electrification research, this work focuses on commercial kitchen electrification because that is where California's building decarbonization efforts have encountered the greatest resistance so far. This work hopes to add much-needed nuance to this policy debate and to point to potential solutions to the commercial kitchen electrification challenge. By doing that, the ultimate goal of this research is to provide actionable information that can fill current information gaps and also point to areas where additional research is needed. With this design, this research is designed first and foremost to help practitioners in the field determine electrification feasibility for

their own kitchens or design public policies and incentives that seek to improve the feasibility of kitchen electrification.

In seeking to fulfill these three criteria, this work undertakes its interdisciplinary approach with respect for each of the research fields weaved into this work. The ultimate goal is to ensure that the chapters and research fields complement and converse with each other and produce a sum greater than its parts to the benefit of restaurant owners, policymakers, and others working to smartly decarbonize residential and commercial buildings.

Chapter 1: Culture and Energy Transitions

Theoretical Background

Food as Signifier of Culture

Underlying the gas stove debate – and one of the focuses of my research – is the intrinsic emotional and cultural significance of food and food preparation techniques to societies. (Hastorf, 2016) Cooking is much more than simply applying heat to ingredients. It is a fundamental part of an historic tradition that helps to order societies and regular relationships. As UC Berkeley archeology professor Christine Hastorf writes in *The Social Archeology of Food*:

> *A cuisine is a unique and consistent set of ingredients, cooking techniques, and flavor principles, carrying psychological, social and religious attitudes towards food, eating practices, and meals. … As a style is a way of doing things, cuisine is the style of an eating tradition. It is the larger system of rules that weaves together foodstuffs, technologies, recipes, and table manners through time and space, but also moral, cosmological meanings and tastes of meals in a social milieu, making the combination of meals and their ingredients choreographed and stylized for the viewer. (Hastorf, 2016)*

Theorist Claude Levi-Strauss developed this concept in his seminal work "The Culinary Triangle," which portrayed grilled meats cooked over fire as a less "elaborated" type of food preparation while defining boiled meats requiring a cooking vessel holding water as a modern, or more elaborated food preparation technology. (Levi-Strauss, 1966) Based on this scheme, different food preparation techniques represent what Levi-Strauss distinguished as different levels of "nature" and "culture," with culture being food preparation techniques involving more human mediation in the cooking process. The modern foodie movement also draws on these theories of food as status and moral signifiers, although in an opposite way, with its emphasis on natural, organic, and raw foods as opposed to manufactured, manipulated, or inauthentic foods. (Wrangham, 2009) In this case, foods that involve less human mediation are viewed as more evolved as opposed to foods that include chemicals and preservatives and are prepared in a microwave oven or on a stove - kitchen technologies that some food connoisseurs see as un-natural or even perversions of natural food preparation techniques.

Beyond concepts of modernity and artificiality, food traditions can tap into issues such as cultural and national identity, gender roles, societal hierarchies, ritual, values, and other organizing principles of societies. That

means that any discussion of changes to food preparation and cuisine fundamentals such as the heat source for cooking food necessarily taps into this network of values and social structures that food cultivation, preparation and consumption imply. In her seminal work *Purity and Danger*, theorist Mary Douglas describes how such conceptions about food and cooking reinforce existing social expectations, especially about the type of behavior that is acceptable within the group. Douglas, in particular, explores the concept of taboo, or unclean, foods in the chapter "The Abominations of Leviticus" and shows how such concepts enforce existing structures or "a systematic ordering of ideas." (Douglas, 1966) As Douglas writes, "In general, the underlying principle of cleanness in animals is that they shall conform fully to their class. Those species are unclean which are imperfect members of their class or whose class itself confounds the general scheme of the world." (Douglas, 1966) As is common in most societies, those in power define and enforce "the general scheme of the world," and violating that general scheme means challenging the powerful and thus risking ostracism or even banishment from the group.

As Douglas shows, these were not trivial considerations for the ancient Israelites, and they resonate even in this time when banishment from a tribe doesn't usually carry lethal consequences. As the deep fractures within U.S. politics and society reveal today, tribal affiliation is still an intense social organizer - one that can determine a person's professional and personal success and social networks. So whether electric induction cooking is considered pure or not carries significant emotional resonance, consciously or subconsciously, and can determine the success or failure of pro-electrification policies. Flame cooking, however, is not just any random food preparation consideration. It is arguably *the* prototypical cooking element, having occupied the center of human cooking practice for tens of thousands of years. As Richard Wrangham writes in *Catch a Fire: How Cooking Made Us Human*, cooking with flame very well may have freed the human body hundreds of thousands of years ago from expending energy on chewing and digesting foods and instead allowed humans to develop brains capable of rational deliberation – in essence, enabling humans to become human. (Wrangham, 2009) With this evolutionary history in mind, people's emotional attachment to flame makes sense even if an induction stovetop can do just as good a job at stir-frying a Chinese pepper meat dish as flame can - a claim that this work will test in chapter four.

Food as Signifier of Community Membership

Building on this conceptual foundation, Elizabeth Rozin's article "The Structure of Cuisine" deconstructs food and food preparation as vehicles for specific culture and values by pointing out how different flavor profiles and food preparation techniques distinguish nations, regions, states, and ever smaller

subgroups as unique cultures and subcultures. In what comes closest to a thesis statement for this chapter, Rozin writes:

> *People who define themselves as a group express or interpret the general human practice in their own individual terms, and it is this individual style or expression of universal culinary activity that we call cuisine. Every culture cooks, but each is intimately bound to its own unique and individual culinary practice (Rozin, 1982)*

As one example, she writes, soy sauce necessarily connotes that the food one is eating is from the East Asian tradition and not from the European tradition. But then, the use of garlic, molasses, ground peanuts and chili tells the eater that the food is from the Korean peninsula and not from China or Japan. (Rozin, 1982) Flavoring principles, as Rozin describes it, can also distinguish different regional cuisines within a country - for example, fermented black beans and garlic typifies cuisine from Guangdong in southern China compared to soy bean paste, garlic, and sesame oil commonly used in dishes from northern China near the capital of Beijing. The same cultural variation in cuisine applies to food preparation techniques, Rozin writes.

> *The same kind of complexity and variability can be found in the framework of the second structural element of cuisine, manipulative techniques. For even though there are a limited number of techniques or processes by which humans characteristically manipulate their foods, any given technique does not inevitably produce the same result. Variations in technology for the same general process can substantially affect the finished product. For example, a steak cooked over a direct fire of hickory wood will be distinguishably different from a steak cooked over a direct fire of dried cow dung, though the cooking technique for both is essentially the same. (Rozin, 1982)*

Based on Rozin's framework, to belong to a distinct community means preparing and eating foods specific to that community, among other unique identifying traits. Such food traditions - or rather, different food traditions - help demarcate people who come from outside of that community. She writes: "The definition that flavoring provides is both inclusionary and exclusionary; it imparts a culinary identification and sense of familiarity for those individuals who create and share in the tradition, while providing as well a defining marker for those outside the group who do not participate in it or who do so only occasionally." As applied to the electric induction stove debate, this theoretical framework highlights the potential concerns around inclusion and exclusion that any kitchen electrification policy will need to take into consideration if it hopes to initiate wide-scale induction technology adoption. Flavoring principles and food preparation practices are important if not central markers of community so

discussions about transforming food preparation techniques should adopt a community-wide scope including consideration of that community's hierarchies, values, and traditions.

Emiko Ohnuki-Tierney spotlights another example of food as a proxy for group identity in her book *Rice as Self: Japanese Identities Through Time*. As Ohnuki-Tierney writes, the Japanese have for centuries used rice as a concept to understand themselves and to distinguish themselves from other nations. "As a metaphor for the self of the Japanese, rice is necessarily involved when the Japanese situate themselves in their interaction with the rest of the world," she writes. (Ohnuki-Tierney, 1993) Part of the power of rice as an organizing concept for Japanese identity is the common practice of sharing rice among members of social groups in Japan and its potential function in social exchanges (Ohnuki-Tierney, 1993). *Bitter and Sweet* by Ellen Oxfeld also identifies food as a vehicle for commensality and exchange within and among tribes. (Oxfeld, 2017) Oxfeld's book goes on to explore in great detail the concept of food as an enforcer of community affiliation, whether that community is a province, village, or family. Through direct observations and interviews in a Southern Chinese village, Oxfeld describes the role of cooking, food, and feasting in preserving community memory, enabling social exchanges that enforce interpersonal ties, creating conviviality that strengthens emotional attachments among community members, expressing the community's moral codes, and reinforcing gender-based labor roles within the community. In particular, the book emphasizes how the physical act of cooking itself can serve those functions, whether it is village women sitting together for weeks to prepare foods for their village's annual Zoufu festival or the concept of "sharing a stove" as a proxy for household formation. (Oxfeld, 2017) Again, Oxfeld's work emphasizes how deeply the values and social structures reinforced through food are rooted in people's cultural identities. What's at stake is not just how one heats food or even how one eats it. How food is grown, prepared, eaten, and shared has the power to define people's social, moral and spiritual universes, especially in cultures that place food at the core of identity.

Food as Signifier of Community Morality

Building off of the work of Oxfeld and Ohnuki-Tierney, one can deduce that a disruption, or even a perceived attack, on foodways and food cultures can be interpreted by some as an attack on the community itself, and the degradation of foodways can provide evidence of the larger deterioration of cultural cohesion and institutions. Pawlowska-Mainville offers one example by describing how for the Asatiwisipe Anishinaabeg people in Northern Manitoba, Canada, protecting their traditional methods of hunting and gathering is central to protecting their integrity as a sovereign nation. Pawlowska-Mainville writes: "Asatiwisipe Ashinaabe aki miijim is not just a system that is food-centered: it is a

complex structure founded on social organization and a mode of production that reaffirms Anishinaabeg economy and identity. Aki miijim is a sovereign food system ruminative of a cultural landscape." (Pawlowska-Mainville, 2020) Extending these concepts to this work, talking to a restaurant based in a specific culinary tradition about giving up flame cooking could be seen as naïve at best and, at worst, as a threat to that group. That's why the case for electrification should focus on more than whether induction stoves can reproduce the thermodynamic processes of gas stoves. Such arguments must also consider the symbolic role flame cooking plays in that culinary tradition and the values at play when asking a restaurant to abandon gas-powered stoves.

Michael Owen Jones, in the article "What's Disgusting, Why, and What Does it Matter?", argues that people's food preferences inherited from the surrounding culture are so strong that they can prompt involuntary responses such as gag reflexes and other reactions to foods that one, and one's larger society, consider inedible or taboo. Jones writes, "While disgust is probably common in the human species (its universality having yet to be demonstrated conclusively), it appears to be the product of nurture, culture, and cognitive development rather than genetics and instinct." (Jones, 2000) As examples of learned bodily reactions to food, Jones cites many Hindus in South Asia traditionally finding beef inedible while Jews and Muslims are taught to reject pork, or many Euro-Americans finding grasshoppers and dogs inedible, to the point that consuming such taboo items or even thinking about consuming them can produce involuntary gag reflexes. (Jones, 2000) In these cases, cultural tradition is felt in the body beyond the powers of deliberation. Rozin similarly writes of the unconscious power of cuisine: "We are under most circumstances unaware of these rules, just as we are unconscious of the rules of syntax that govern our utterances." (Rozin, 1982) Nonetheless, disgust, even if felt unconsciously, Jones writes, taps into larger organizing social concepts such as "'distinction, class, education, wealth, talent'; it also involves notions of civility and propriety; of differentiating, ranking, and segregating people; and of expressing 'a social and moral sentiment.'" (Jones, 2000) This echoes the analysis of Douglas, Oxfeld and Levi-Strauss in connecting foodways with one's own sense of human development and one's place within a society.

While these learned beliefs about food may be held unconsciously, they also can be explicitly expressed to reinforce a group's rules and expectations about fertility, hierarchy and gender, as described in Anna Meigs' article "Food as a Cultural Construction." In particular, Meigs writes about the different food customs of the Hua people in Papua-New Guinea, especially in relation to ideas about bodily purity and pollution. For example, rules about acceptable diet often apply to pregnant women and women who are menstruating based on the group's beliefs about bodily forces and the bodily energies that ensure healthy births. (Meigs, 1997) Age-based hierarchy is reinforced among the Hua

through food rules that prohibit people from eating pigs raised or shot by someone from a younger generation or eating produce from a garden tended by someone from a younger generation. (Meigs, 1997) These sorts of rules reflect a larger cosmology about energy transference, or *nu*, among generations and echo the food laws that Douglas cites among the ancient Israelites as not just confirming one's membership in a tribe but identifying one's place within that tribe and the expectations one must be mindful of to retain that place. (Douglas, 1966) In this way, foodways can be seen as a microcosm for the entire tribe and how its members are expected to function within it. The fact that food came to carry such a heavy symbolic load for tribal membership and structuring is not surprising considering Wrangham's description of food preparation's central role in enabling the evolutionary leaps that distinguished humans from other animals. (Wrangham, 2009) We are who we are as a species because of the unique way we prepare our foods, and reaffirming our food practices reaffirms who we are as humans.

Food as Connection to Home Cultures

Lidia Marte, in her ethnography of Dominican immigrants in New York City, transports this concept of food as a vehicle of tribal identity and values far from the tribe itself in her analysis of people living away from their native homelands. (Marte, 2007) In particular, Marte shows how the preparation of *la bandera*, or the Dominican staple meal of rice, beans and meat, both emotionally connects immigrants from the Dominican Republic to their homeland and empowers Dominican women to emotionally transport household members home through their control of food preparation. Marte writes: "This working-class meal became a prominent national culinary representation, together with *sancocho* and *mangu* (mashed green plantains) after a massive Dominican emigration between the years of 1960-1990 became established as a visible diaspora in the US." (Marte, 2007) Of a woman named Elsa who spent much of her day buying ingredients around New York City and cooking for her family, Marte writes: "These food narrative memories obviously mark her gendered body and created an echo in the way she reclaims place and sense of 'home,' and space for her survival in the present from her local grounds in NYC." (Marte, 2007) In other words, specific foodways can hold additional emotional resonance for immigrants both as a fragile connection to the countries they left behind and as a vehicle for recreating the comforts and traditions of that homeland in their own households - an empowering process. Transplanted to an often confusing new location, immigrants can find order and a comprehensible space in their native foods. On top of that, food's transporting power comes not just from its tastes and textures, but also the way that it is produced. Marte calls this culinary topography "foodmaps" covering the markets where ingredients are purchased, the herbs that family members from back home send to New

York-based immigrants, and the memories of home that the foods conjure up for both the cooks and the eaters. (Marte, 2007)

As a side note, this theoretical background raises the possibility of using food traditions and culture to do something different than what's been described so far: to challenge traditional social structures such as gender and socioeconomic hierarchies. If indeed these hierarchies are embodied by culinary traditions, can they be dismantled or at least altered by altering the culinary traditions themselves? Cowan, in her book "More Work for Mother," describes the evolution of domestic technology such as vacuum cleaners, dishwashers, and refrigerators during the 20th century to essentially trap women in such household work roles. (Cowan, 1983) As a counterpoint, Cowan proposes the idea of introducing other domestic technologies and practices such as the communal kitchen or shared domestic employees in overturning this gender-based household labor system. (Cowan, 1983) This line of inquiry at least opens a window of exploration into the potential for new cooking technologies in commercial kitchens to challenge traditional practices and assumptions that have long ordered the routines of restaurant work. For example, could the faster cooking times and more efficient heat transfer processes of electric induction stoves improve the safety environment of restaurant kitchens and reorder what appears to be a soft gender dynamic in many commercial kitchens - that of the men working the grill while the women work the cash register and prep station? This work does not examine this potential in depth but raises this question as an avenue of possible future research.

Applying the larger concept of food serving as a vehicles for communicating and perpetuating social and cultural norms, one oft-cited challenge to kitchen electrification efforts has been the perceived difficulty of electrifying Chinese restaurants, who often use high flame under woks to quickly stir-fry food. One Chinese restaurant owner in Los Angeles described his chefs leaving the gas burners on for three hours straight during the lunch rush and throwing ingredients into a wok for about a half-minute of frying before moving onto the next order. (Chang, 2022-2024) In Beijing, even the stoves in middle-class two-bedroom apartments come with restaurant-grade natural gas-powered burners designed for wok cooking over intense flame.

Some cultural traditions have historically viewed flame cooking as a core element of identity and cultural relevance and, in some cases, as essential to bodily health and balance. For example, traditional Chinese medicine classifies different types of bodily heat that can produce diverse types of illnesses or conditions within a person and that can only be cured with a specific way of applying heat or cold to a person's body. (Liu et al., 2021) Traditional Chinese medicine also includes the symbolic concept of using "heart fire or clearing heat" to cure symptoms such as fever, irritability, and delirium. (Liu et al., 2021) In

Chinese daily life, such concepts of medicinal heat can inspire the avoidance of consuming cold liquids during the day to avoid disrupting the thermal balance of a person's body or the use of intense flame to cook foods to transfer healing heat to the consumer. Similarly, cooking with flame is sometimes seen as authentic and genuine compared to what's considered the artificial practice of cooking with electricity. This attitude appeared repeatedly in the short interviews conducted for this work in which several respondents of different racial backgrounds stated that cooking with fire was the "natural" way to cook.

The question for kitchen electrification advocates is whether cooking over intense flame is indeed an unnegotiable part of Chinese American national identity just as Marte describes la bandera representing their home culture for Dominican immigrants. (Marte, 1982) If so, asking Chinese restaurants to give up their wok and flame cooking and switch to induction stoves could be akin to asking them to start serving tacos and quesadillas. This same line of questioning applies to other types of cooking in American immigrant communities, whether it's grilling beef to make carne asada tacos or browning Indian roti flatbread. These food preparation techniques could in fact could tie immigrants to their home countries, and that could at least in part explain the resistance of several Chinese restaurant owners interviewed for this work to giving up flame cooking.

Taken as a whole, this rich body of research and theory highlights important considerations for policymakers and advocates seeking to overcome restaurant resistance to kitchen electrification. How one prepares food is merely the above-the-surface manifestation of an extensive system of spiritual, moral, cultural and political values that define who we are as humans. Approaching kitchen electrification as only an engineering or an economic puzzle is missing a big part of this picture. To be sure, commercial kitchen electrification faces other enormous challenges, in particular the high up-front cost of purchasing induction equipment, the need to upgrade electrical and ventilation systems, and the time and cost of retraining professionals who have built successful careers cooking with flame. However, even if governments were to completely subsidize these up-front expenditures as well as provide restaurants with staff training resources, the more personal dynamics of this transition, as described in the literature described here, could still present a big obstacle for restaurants and chefs when asked to take the leap and switch to electric induction cooking. Again, this research does not offer policy prescriptions for electrification, but it does raise a salient and previously unexplored part of the kitchen electrification debate that needs to be taken seriously and further explored.

Finally, this body of literature represents a real treasure trove for researchers and policymakers trying to understand the cultural context for commercial kitchen electrification, especially in relation to specific cuisines or

kinds of dishes. This research aims to build on that literature by generating new insights into the expectations people often have of specific culinary cultures and how those expectations are shaped by their cultural narratives and traditions. Taken as a whole, this literature represents a promising foundation for further examinations into the social meanings and personal attachments around food that kitchen electrification efforts have already awakened.

Research Project 1: Gauging Restaurant Customer Expectations

Project Overview

This research explores the cultural and social dynamic of kitchen electrification by conducting short interviews with 107 people about their expectations for flame and electric cooking in restaurants and how certain dishes are prepared. In particular, this research gauges how different customers view whether flame cooking or the end results specific to flame cooking are essential to their evaluation of restaurants.

Objectives

This research aims to produce a useful reality check to what restaurant owners and chefs believe their customers want from specific types of foods. This research focuses on people's beliefs and expectations and doesn't examine the actual thermodynamic results of flame versus electric induction cooking process. As designed, this research can help answer three questions that examine culinary expectations:

A. How do people envision the preparation of certain foods?

B. Will they accept non-flame-based alternatives to cooking those foods?

C. Even if people prefer flame-based cooking, how highly do they prioritize that preference? In other words, would an induction stove be a deal-breaker when customers decide where they'll eat out?

Referring to the California Restaurant Association lawsuit against the City of Berkeley, this research aims to address its contention that "Restaurant owners and employees as well as restaurant customers also will be denied the use of gas appliances to prepare food, heat their homes or water, or use gas fireplaces in newly constructed buildings." (California Restaurant Association, 2019) This quote speaks to supposed customer expectations that their food will be prepared on gas appliances – a supposition that this research aims to test.

Theoretical Background

The concept of food as an expression of culture, class and even politics has been well-established. To quote just one example, French theorist Roland Barthes wrote in his 1962 piece "Toward a Psychology of Contemporary Food Consumption":

> *To eat is a behavior that develops beyond its own ends, replacing, summing up, and signalizing other behaviors, and it is precisely for these reasons that it is a sign. What are these other behaviors? Today, we might say all of them: activity, work, sports, effort, leisure, celebration – every one of these situations is expressed through food." (Barthes, 1962)*

Using this analytical lens, this research attempts to determine which values and behaviors are signaled by flame cooking versus induction cooking. When a restaurant emphasizes "grilled" in the names of its dishes, what is the restaurant communicating to potential customers about its values and its positioning in the larger culinary culture? And conversely, what does induction cooking signify to customers? Also, what concerns does electric induction cooking trigger among specific demographic groups with their own culinary traditions? And what are the narratives that different cultures have about the "correct" way certain foods should be prepared and consumed?

One final area of inquiry is that of customer expectations regarding the use of flame cooking in different cuisines. For example, an up-scale Emeryville taqueria, C Casa, has highlighted in its menu its flame-based cooking methods presumably because the restaurant's owners believe flame cooking connotes to customers a desired flavor profile for its dishes and a general higher level of culinary quality. As a result, customers may be willing to pay a premium for flame-cooked meals, which may be reflected in the restaurant's higher prices. For example, a steak taco at C Casa cost $10 in November 2024 compared to $4.80 at the Bay Area-based mini chain Gordo Taqueria while a chicken quesadilla cost $19 at C Casa compared to $8.15 at Gordo. (C Casa; Gordo, n.d.) This raises the question of whether customers actually expect certain dishes to be cooked with flame if they are to pay more for them and whether they will choose a restaurant primarily based on its use of flame in the kitchen regardless of price.

Methods

One hundred and seven respondents answered a set of five to nine questions (including possible follow-up questions) in short interviews conducted in person from July 6, 2024 to August 4, 2024 at eight farmer's markets, a swap meet, and a food festival around the San Francisco Bay Area. Each interview

lasted from one to six minutes depending on the interest of the respondent. The survey set an initial sample size at 50 interviewees based on the experiences of qualitative researchers finding that little new information is generated after interviewing about 20 people belonging to one analytically relevant participant category and that studies employing individual interviews conduct no more than 60 interviews before reaching a point of data saturation. (Vasileiou et al., 2018) In the end, this survey questioned 107 respondents in 10 different sites in large part to capture enough people of each representative ethnic group to create meaningful results for that group and as a whole. The interview sites were farmer's markets in El Sobrante, downtown Berkeley, the Temescal and Montclair neighborhoods of Oakland, the Bay Area Rapid Transit station in Castro Valley, the Hayward civic center, downtown Campbell, and Creekside Park in Cupertino, as well as at the Coliseum Swap Meet in East Oakland and the 626 Night Market at the Alameda County Fairgrounds in Pleasanton. The survey aimed to interview people who are demographically representative of the region and have no direct associations with the restaurant industry. To achieve that diversity of representation, respondents were asked at the end of the survey to self-identify their gender and race.

The self-identified demographics of the survey respondents were:

53 Female

53 Male

1 Gender queer

37 Hispanic - including one self-identifying as Puerto Rican

35 White non-Hispanic

18 Asian, including two self-identifying as Indian and one self-identifying as Persian

12 Black

1 North African

3 Native-American

1 Decline to state

The survey was conducted in three languages - English, Spanish, and Mandarin - with respondents allowed to read the questions from the page if doing so helped their comprehension. Only the two respondents who spoke Mandarin read the questions from the page in addition to having the questions

verbally explained to them in Mandarin. The linguistic breakdown of the interviews were:

81 interviews conducted in English

23 interviews conducted in Spanish

3 interviews conducted in Mandarin

When cross-categorizing by gender and race or ethnicity, the respondents' demographic profiles were as follows:

16 Female Hispanic

21 Male Hispanic

18 Female White

16 Male White

1 Gender Queer White

11 Female Asian

7 Male Asian

7 Female Black

5 Male Black

3 Male Native American

1 Male North African

1 Female Decline to state

The demographic breakdown of the survey sample roughly tracks with the demographic breakdown of the total California population, according to the U.S. Census Bureau.

Hispanic percentage of sample - 34.6%

Hispanic percentage of population - 39.4%

Non-Hispanic White percentage of sample - 32.7%

Non-Hispanic White percentage of population - 34.6%

Asian percentage of sample - 16.8%

Asian percentage of population - 15.4%

Black percentage of sample - 11.2%

Black percentage of population - 5.6%

Native-American percentage of sample - 2.8%

Native-American percentage of population - 1.6%

Survey Instrument

The author personally conducted all of the interviews following an interview script with some variations added when respondents asked for clarification. The interview script in English read as follows:

UC BERKELEY FOOD PREFERENCE SURVEY DESCRIPTION:

California is trying to reduce greenhouse gas emissions by encouraging the transition from natural gas use to all-electric heaters and stovetops in buildings. This survey aims to gauge how customer expectations about food preparation can impact these transition plans especially in restaurants looking to electrify their kitchens. These survey results will be used in energy research based at UC Berkeley looking specifically at commercial kitchen electrification. Thank you for answering the following five sets of questions.

Q1: When you think about meals you like eating, do you consider the way in which they are cooked (i.e., grilled, boiled, fried. . .), in addition to what is in them? YES or NO

Q2: Do you consider how food is cooked in a restaurant's kitchen when you choose which restaurant to dine out in? YES or NO

If Yes, what's important to you about how a restaurant cooks its food when choosing where to eat out?

Q3: Would you have any hesitation eating at a restaurant that only used electric, non-flame-based cooking? YES or NO

If Yes, what would be your concern about eating at an all-electric restaurant?

Q4: Are there any foods that you think can only be cooked on flame to taste good?

YES or NO

If Yes, which foods?

Q5: Have you ever cooked on an electric induction range? YES or NO

(See Appendices A and B for the Spanish and Chinese versions of the survey script.)

The survey questions were designed to progressively introduce to the respondent the concept of food preparation as part of a meal's identity, and then to evaluate how the respondent incorporated heating technique and food preparation practices into their conception of foods. The questions also sought to answer whether respondents considered food preparation techniques when choosing which restaurant to eat at.

The survey's question-by-question thematic strategy was as follows:

Question 1 is designed to introduce the overall concept of food preparation as a culinary element and seeks to gauge the respondents' lived experience of food - whether solely as a consumer without much awareness of how food is prepared or as a connoisseur with specific preferences as to how food is cultivated and prepared as part of their conceptions of certain dishes.

Question 2 addresses potential restaurant owner assumptions about whether customers expect flame cooking when they choose where to eat out or whether they are agnostic as to how a restaurant cooks its foods. If their customers in fact don't consider food cooking practices when choosing where to eat out, that could remove a perceived customer preference barrier for restaurants considering kitchen electrification.

Question 3 addresses customer expectations as to how food is cooked in restaurant kitchens and whether restaurant perceptions of customer expectations are realistic or not. If customers do not have any preference as to

flame or electric cooking in the restaurants they eat at, that could remove another potential psychological barrier and business consideration in a commercial kitchen's decision whether or not to electrify.

Question 4 serves as a counterpoint to Research Project 4, which evaluates the ability of electric induction equipment to duplicate the flavors and textures produced in certain dishes by natural gas-powered cooking equipment. This question gauges the perceptions of customers about the ability of electric cooking to prepare foods as customers expect them to be prepared. If customers' expectations are worse than the range of results that electric induction equipment can actually produce, that could be an area for public education into the real capabilities of electric cooking technology. Otherwise, if customer beliefs reflect the actual limitations of electric equipment to produce comparable flavors and textures as what can be produced by gas-powered cooking equipment, then public education about the capabilities of induction stovetops would not help overall adoption of the technology. As a work-around, kitchens could adopt dual fuel equipment such as propane canisters to power mobile stoves or wood-fired ovens. At least one commercial kitchen based in Reno, Nevada, has both electric combi ovens and wood-fired pizza ovens to electrify its food preparation process where possible while still delivering the flame-cooked dishes that customers expect.

Question 5 responds to arguments often made by electrification advocates that public unfamiliarity with electric induction equipment is the main obstacle to electrifying kitchens, and that once restaurants and the public in general learn about the technology, they will appreciate its superiority over gas-powered cooking technology and make the switch. With this line of questioning, it is possible that respondents will be familiar with electric induction technology but still prefer gas-powered equipment due to personal cultural beliefs they have about the importance of flame cooking.

The respondents often added more insights to their responses, which at times addressed the beliefs behind their responses or added contextual information. Overall, these survey questions are designed to both capture the respondents' personal attitudes toward food and food preparation techniques as well as their decision-making process when choosing where to each out. This survey instrument also aimed to capture what can be a nebulous concept: people's sense of culinary culture, as expressed in specific preferences for certain food preparation techniques, and how that culture determines their receptiveness to non-flame based electric cooking. Taken together, this survey aims to ultimately help restaurants gauge potential customer acceptance or rejection of food cooked in an all-electric kitchen as they determine the potential business impacts of kitchen electrification, and possibly trace those

customer preferences to specific cultural narratives and expectations around food.

Contributions to Literature

This research adds a unique customer-based perspective to the commercial kitchen literature by addressing cultural expectations around flame cooking in food preparation and the role of food preparation in people's conceptualizations of certain dishes. This research provides insight into what sort of cultural cachet comes with cooking with flame and explores whether that cachet varies with different types of cuisines. This research also teases out the cultural origins of that preference for flame-cooking or for certain textures and flavor profiles. Finally, this research compares findings about customer expectations of cuisines with restaurant owner assumptions of customer expectations.

The current kitchen electrification literature generally does not address the cultural dynamics of restaurant electrification as expressed either in how flame cooking fits into the cultural worlds of specific dishes or how customers expect certain foods to be prepared in the ways they historically have been cooked on flame. By placing the commercial kitchen discussion within this cultural context, this research opens up a new area in the burgeoning field of energy folklore literature by connecting the current predominantly quantitative side to existing electrification research with the extensive literature examining how food cultivation, preparation, and consumption is shaped by and shape social values and orders. This work argues that such cultural values are central to the electrification discussion and could determine whether customers accept or reject changes in how commercial kitchens prepare their meals.

Finally, this research contributes a survey-based approach to the existing literature. These survey questions originated from both conversations with restaurant owners and from the literature described in the Theoretical Background section of this chapter. As Rozin writes in The Structure of Cuisine, food preparation, along with flavor profiles, is a core element in each culture's culinary self-conception. (Rozin, 1982) By asking people about how they view food preparation and flavor profiles, this research applies the theory to a live public policy debate. At the same time, this research expands the theoretical field with data on the current debate about electric induction cooking.

If anything, this research has demonstrated the resilience of much of the classic theory around food and culture and its lasting ability to say something important about people's deeply felt connections to their cultural foodways. Hopefully, this research helps apply this classic literature to a new and dynamic

policy context where it can help advance understanding of possible restaurant and customer resistance to restaurant electrification initiatives.

Results

The survey responses revealed several clear trends that illuminate both the challenges and the opportunities for policymakers and advocates seeking to scale electric induction technology use in commercial kitchens. First, regardless of race or gender, the overwhelming majority of respondents said flame cooking was a necessary element of certain dishes such as grilled meats and vegetables as well as specific regional foods. That finding comports with the emphasis that restaurants such as C Casa Taqueria place on grilled foods in their menus and branding. (C Casa, n.d.) In particular, 33 out of 37 Hispanics surveyed answered yes to Question 4 that some foods must be grilled over flame to taste the way they should taste. When asked which foods needed to be grilled, almost all Hispanic respondents said meats and vegetables as well as tortillas - the very foods that make up the weekend parrilla, or barbecue, that anchor so many family gatherings in Latin America. That result underlines a personal observation that in Argentine, Brazilian and other Latin American cultures, grilling meats and vegetables on flame is *the* communal activity that brings together friends and family, and the identity of many dishes is rooted in the act of grilling them over fire in a communal setting. As Marte writes in her article on Dominican immigrants in New York, food preparation traditions are part of the foodmap of these cultures, connecting immigrants to their homes and empowering cooks as they survive in an adopted culture. (Martes, 2007) And as Oxfeld describes in her book *Bitter and Sweet*, the sharing of food can serve as an important glue for communities and reinforce generational ties for families otherwise living far apart geographically. (Oxfeld, 2017) In the context of grilled foods, cooking with fire can both reaffirm cultural ties and relationships for many immigrants.

The survey responses also found that despite preferences for flame cooking with certain foods, most people were open to eating at restaurants that only used electricity-powered cooking. Many survey respondents said they did consider restaurant kitchen practices when deciding where to eat out but those concerns mainly centered around hygiene and cleanliness in the kitchen. In other words, for most survey respondents, electric induction cooking does not trigger any inherent emotional responses such as those described by Jones. (Jones, 2000) While cooking with flame appears to be a core part of some culinary traditions, diverging from that tradition and cooking with electric stoves is not in itself a cause for rejection. This finding implies that for dishes without a specific connection to flame cooking, many customers would accept electric induction technology in their restaurants.

One final high-level take-away from these survey results is that although about half of the respondents said they had tried cooking with electric induction stoves, about half of those people still preferred cooking with gas-powered stoves. This finding casts doubt on arguments used by kitchen electrification advocates that lack of familiarity with electric induction equipment was a top barrier to consumers and restaurants adopting the technology. This survey suggests that seeing is not necessarily believing when it comes to electric induction cooking and that other considerations such as people's cultural values around flame cooking may apply as much weight on people's attitudes toward how they prefer to cook their foods. One caveat to this finding is that most of the respondents who said they had tried cooking with an electric induction stove also said they had tried it only once or twice, for example at a family member's house during a periodic visit or at an AirBNB rental while on vacation. That finding opens up the possibility that more regular use of an induction stove could create more comfort with the technology and engender a more favorable opinion of it. In fact, several people who said they regularly cook with induction stoves said they thought such stoves worked just as well as gas stoves in the kitchen. But even these respondents, the emotional connection to flame endured. As a white woman interviewed at the Temescal farmer's market in Oakland said, she was nervous at first using an induction stove but then learned to enjoy cooking on it. Still, she said she didn't believe induction stoves could replace the "romantic," "primal," and "traditional" experience of cooking with flame.

Put another way, the mental narrative this woman had of cooking was still based in her conceptions of flame cooking as a kind of sui generis manner for preparing foods. Her statement hearkened to the importance of addressing people's mental models of energy properties when communicating to them about transitions to cleaner fuels, as described in the energy folklore research of several Plymouth University researchers in the United Kingdom (Goodhew et al., 2017). Their work examined the mental models that working-class English households had of how their home's heating systems worked in the context of local government efforts to move people from coal to natural gas-powered heat.

In her study, Goodhew et al wrote:

> *Research into mental models has found that when individuals hold models of physical systems, these models tend to be stories or representations. They are 'models' in that individuals use them to predict the outcomes of their actions and so guide behaviour. However, mental models are not the formal scientific models, concepts or theories characterised by abstraction, predictability and consistency. Mental models may change over time and are not necessarily real or correct; they can be fuzzy, incomplete, and conflicted. However, a mental model can be seen as an*

abstract (folk) theory in that individuals may group mental models into analogies to refer and explain similar phenomena they encounter. (Goodhew et al., 2017)

Similarly, Oxford University researcher Sarah Darby stressed the importance of personal stories and mental concepts when understanding people's attachments to certain energy technologies and designing policies encouraging their adoption of other technologies. (Darby, 2017)

Darby writes:

...[E]nergy transition stories can emerge from lived experience and social learning, as well as from a policy blueprint or high-level scenario: transition is enacted, experienced and expressed in personal and local terms, not only as a grand progress of technological innovation and adoption. (Darby, 2017)

This research in essence is attempting to build a narrative of how people from different ethnic groups view food and their culinary culture, and how those narratives might accommodate the introduction of induction stoves. While this work does not propose ways to change those narratives, it highlights the diverse factors that help create those larger stories.

The following section takes a closer look at the responses to each survey question and discusses their potential implications for commercial kitchen electrification.

Table 1: Responses to Survey Question 1 by Race: When you think about meals you like eating, do you consider the way in which they are cooked (i.e., grilled, boiled, fried. . .), in addition to what is in them? Note: Total includes 1 decline to state

	Total	Hispanic	White	Asian	Black	Native American	North African
Yes	87	26	31	13	12	3	1
No	20	11	4	5	0	0	0

For Question 1 about the consideration of cooking techniques used in favorite dishes, 87 people responded that they did consider how their favorite dishes were cooked as part of their conceptualization of the dishes, while 20 people said they didn't consider how the dishes were cooked. Compared to other respondents, more Hispanics, 11 of the 37 surveyed, said they did not consider cooking techniques in their conceptualization of the dishes, while all Black respondents said they did consider cooking techniques as part of their favorite dishes. Several respondents said they avoided fried foods for health reasons while others said they favored grilled foods especially for meats such as

chicken. Notably, most of the respondents who said they did consider cooking techniques as part of their favorite dishes cited flame cooking or grilling as part of that preference, along with several respondents who said they avoided fried foods.

Table 2: Responses to Survey Question 2 by Race: Do you consider how food is cooked in a restaurant's kitchen when you choose which restaurant to dine out in? Note: Total includes 1 decline to state

	Total	Hispanic	White	Asian	Black	Native American	North African
Yes	63	26	20	7	6	3	1
No	44	11	15	11	6	0	0

For Question 2, 63 people responded that they did consider restaurants' cooking techniques when they decided where to eat out, while 44 respondents said they did not consider restaurants' cooking techniques. Hispanic respondents (26 out of 37 surveyed) were most likely to say they considered restaurant kitchen techniques, with many of them citing kitchen cleanliness, staff hygiene, and quality of ingredients as top considerations. Asian respondents (7 of 18 surveyed) were least likely to say they considered kitchen cooking techniques while choosing where to eat out, with Black respondents (6 of 12 surveyed) were also less likely to say they considered kitchen cooking techniques. Eight respondents specifically said they preferred restaurants that used grilling as part of the kitchen preparation. Vegetarian and vegan respondents said they considered whether a restaurant kept dishes and silverware used to prepare meats and vegetable dishes separate.

This result echoes the discussion above that for some cultures, the identity of foods such as barbecued meats and vegetables is intrinsically connected to the communal act of preparing and eating them. (Oxfeld, 2017) As this survey suggests, this connection of food with context cuts across several cultures. Indeed, the literature has demonstrated that how foods are prepared is often fundamental to their meanings for communities and cultures, such as the Hua people with their rules about who can prepare foods and the bodily qualities that those foods convey to consumers. (Meigs, 1997) Kitchen cleanliness, heating technique, and other food preparation considerations contribute to people's understandings of their cuisine.

Table 3: Responses to Survey Question 3 by Race: Would you have any hesitation eating at a restaurant that only used electric, non-flame-based cooking? Note: Total includes 1 decline to state

	Total	Hispanic	White	Asian	Black	Native American	North African
Yes	25	14	5	5	1	0	0
No	82	23	30	13	11	3	1

The responses were more clear-cut for Question 3 asking whether respondents would hesitate eating at a restaurant that only used electric, non-flame-based cooking. Eighty-two respondents said they would not have any hesitation eating at an all-electric restaurant, while 25 said they would hesitate eating at such a restaurant. Hispanic respondents showed most hesitation out of the respondents, with 14 of 37 saying they would have concerns eating at a restaurant with an all-electric kitchen. Five Hispanic respondents said they specifically preferred gas stoves over electric induction equipment in restaurants. Another 5 respondents - three Hispanics, one Asian, one white - said they were unfamiliar with electric cooking and didn't trust that it could adequately cook foods as well as gas-powered stoves could.

Similar to responses received in Question 1, several people said they would hesitate eating at an all-electric restaurant because they considered cooking on flame "normal" or "healthy" compared to the electric alternative. One black woman interviewed at the downtown Berkeley farmer's market echoed Wrangham's thesis in *Catch a Fire: How Cooking Made Us Human* by noting that people had been cooking with fire "since the start of time." (Wrangham, 2009) Again, this statement points to her mental narrative of what could be called "natural" ways of cooking, traced back to human's earliest evolutionary stages using fire to break down foods before consuming them. Of course, this concept of "naturalness" is subjective. For some, natural foods mean those grown without pesticides or hormones while for others, it means raw foods that have not been heated at all. The point here is that any definition speaks to a personal storyline for "how the world works" or maybe "how the world should work." Any attempts to persuade people otherwise should be designed specifically for their story.

The results of this question suggest that cooking with electric induction equipment does not trigger the disgust or taboo responses associated with certain types of meat or insects for certain questions. Cooking with flame may be considered the "natural" form of food preparation by some respondents, but most of the respondents appeared to hold no other intrinsic aversion to food cooked with electric induction technology.

Table 4: Responses to Survey Question 4 by Race: Are there any foods that you think can only be cooked on flame to taste good? Note: Total includes 1 decline to state

	Total	Hispanic	White	Asian	Black	Native American	North African
Yes	91	33	29	15	10	2	1
No	16	4	6	3	2	1	0

At the same time, respondents were even more unequivocal about Question 4 asking whether some foods could only be cooked on flame to taste the way they liked the dishes to taste. In total, 91 respondents said some foods had to be cooked on flame, while 16 said they did not think any foods necessarily had to be cooked on flame to taste right. Among Hispanic respondents, the most common foods cited as needing to be cooked on flame were carne asada and grilled meats, chilaquiles, sopas and caldos (soups), birria (meat stew), beans, tortillas, chocolate atoles, and enchiladas - a wide range of dishes. White respondents also cited grilled meats and vegetables as needing to be cooked on flame in addition to peaches and pizzas in wood-fired ovens. Black respondents cited barbecue and smoked and charred chicken, fish, and hot dogs. Asian, and in particular ethnic Chinese respondents, cited high heat wok cooking as needing flame with one man listing Sichuan cuisine in particular as needing strong flames to cook quickly to taste right. One woman who self-identified as Indian said flame was needed to cook roti flatbreads, and in particular to produce the puffy texture and charred flavor that she loved in such breads.

This work will test these suppositions about flame cooking in Chapter 4 by using induction stovetops to cook stews, stir-fries, and other dishes cited by respondents as needing flame to properly cook. Even if those experiments show induction stoves can faithfully produce the same results, however, such evidence cannot be relied on to convince people otherwise. This phenomena has been documented in studies by Kruatong et al. and Georgiou et al. showing that high school and even university engineering students' mental models of heat flows did not change even after they learned of the actual physical properties of heat flows that contradicted their earlier mental models (Kruatong et al., 2006; Georgiou et al., 2008). It has been well documented that people's belief systems can be based on culture and values more than scientifically proven facts, and the appeal of flame-based cooking could easily fall into the same category of belief systems.

Table 5: Responses to Survey Question 5 by Race: Have you ever cooked on an electric induction range? Note: Total includes 1 decline to state

	Total	Hispanic	White	Asian	Black	Native American	North African
Yes	51	15	18	12	4	1	0
No	56	22	17	6	8	2	1

This question was usually supplemented with a brief explanation for how induction stoves differed from older electric coil stoves. About half of the respondents (51 out of 107) said they had used induction stoves previously, with Asian respondents (12 out of 18) most likely to report they had used induction stoves while black respondents (4 out of 12) were least likely to say they had used induction stoves. When asked about their experience cooking on an induction stove, people who said they had used the technology before gave diverse responses. Eighteen respondents said they had a good experience with the technology, with some saying they liked that it cooked foods faster. Twenty-one respondents said they still preferred cooking with gas after using an induction stove, with some saying cooking on induction stoves took longer than with gas stoves and others saying they had a hard time adjusting the heat on an induction stove like they could with gas stoves.

The three respondents who self-identified as Native American provided diverse responses. One man interviewed at a Castro Valley farmer's market said he liked grilled, boiled, and baked foods and although he had not tried using an electric induction stove before, he thought that electric induction stoves could bake and sear beef steak better than flame-powered barbecues could. (This statement will be the subject of experiments in Chapter 4 of this work) Two Native-American men interviewed at a Pleasanton night market food festival were more emphatic about their preference for flame cooking, citing burgers, stakes, and yakitori skewers as foods that they believed could only be cooked on flame to taste the way they liked them. One of the men said he had tried an induction stove previously and found it functioned similar to older, coil-based electric stoves.

Several respondents noted that it took a while for them to get used to cooking on an induction stove, such as learning how quickly the stove heats up and how to adjust the heat level. Among those who said they learned how to properly use induction stoves, about half of them said they were happy with the results. In particular, several respondents noted that induction stoves did not pollute indoor air as gas stoves do, echoing the results of a 2020 UCLA Fielding School study finding that gas stoves produce higher levels of carbon monoxide

and nitrogen dioxide than is considered safe by national and California ambient air quality standards. (Zhu, 2020)

Of those who said they had tried an induction stove before, 18 of the respondents said they still preferred flame, citing reasons such as what they said was the greater ease of control with flame or the slower heating time with induction - both counter to induction stoves' usual selling points of more nuanced heating controls and quicker cooking times. Like any new technology, induction stoves have their own adoption curve, and these responses may reflect that gradual acceptance among the wider public. Unlike any new technology, however, induction stoves are designed to replace a millennia-old method of preparing food, and the wariness voiced by some respondents may reflect that fact.

Discussion

These survey responses reveal seeming contradictions in respondent attitudes toward the acceptability of restaurant electric induction technology on the one hand and preferences for flame-based cooking on the other. This result opens up several windows of interpretation. The first result responds to a broader survey question that asked about people's overall acceptance of an electric induction-equipped restaurant while the second question asked respondents about specific dishes needing flame to be cooked properly. While many respondents said certain dishes could only be cooked on flame, a majority of respondents also said they would have no hesitation eating at a restaurant that only used electricity-powered cooking. This split in responses points to nuances in the survey results that could help inform electric induction support programs and open up an avenue for understanding public attitudes. In particular, the survey indicates that most people appear to generally accept electric induction cooking as a restaurant technology, with some vocal exceptions from flame cooking die-hards. This result provides encouragement to electrification advocates that despite the general lack of familiarity with electric induction stovetops voiced by many survey respondents, most people appeared open to the technology being used in commercial kitchens, or at least did not have any pre-emptive bias against it.

The survey results also showed that in general, people's preference for flame cooking applied to specific dishes and was not a blanket preference for flame cooking. That result again provides encouragement to restaurants that are interested in electrifying and that do not specialize in the types of foods some respondents said required flame cooking such as char-broiled or grilled meats and vegetables and certain Chinese regional cuisines. From a gas system planning perspective, this result may present challenges to efforts to

decommission entire branches of gas infrastructure as the obligation to serve a restaurant offering flame-based foods would require maintaining and operating the entire section of that gas system. One work-around would be to incentivize the use of propane canisters or wood fires for just those restaurants that prepare grilled meats, vegetables and other foods that customers expect to be cooked on flame. In any case, this result could provide a workable arrangement for at least starting to electrify a large portion of restaurants before attempting to decommission whole branches of gas infrastructure.

Looking more specifically at the demographic composition of responses, these results show that acceptance of electric cooking is prevalent especially among white respondents who identified themselves as environmentally minded. Many respondents said they were aware of the debate over gas and electric cooking, and that they planned to switch to electric induction cooking if they hadn't already done so. Yet even among these respondents, many of them said they needed flame to cook certain foods such as grilled meats and vegetables. One man at the Temescal farmer's market said that his family used an electric induction stove at home but that he still kept a small gas stove and a propane stove with a wok in the backyard to grill, smoke, and roast certain foods. Black respondents tended to express the greatest attachment to flame cooking, with 10 out of 12 respondents saying certain dishes needed to be cooked with flame, and many citing char-broiled, barbecued, and other grilled foods.

Finally, this survey showed that a substantial number of people are becoming familiar with electric induction technology although that exposure is uneven among different racial groups. Among this sample, black respondents were largely unfamiliar with electric induction stoves while almost all Asian respondents said they had used the technology. The large number of respondents who said they did not have a good experience with induction technology even after using it suggest the magnitude of challenges that induction advocates could face convincing households to adopt it even after trying it. Like with any new technology, electric induction stovetops require a certain amount of repeated uses to become familiar with their operation and to fairly judge their efficacy. That said, this ramp-up time, however, could be an obstacle in itself to electric induction adoption. Gas stoves usually do not require a learning process, due to people's general familiarity with their operation. If people need to learn how to properly use electric induction stoves, even if that education takes a few minutes, that requirement could depress the adoption rate especially among people already intimidated by new technology.

One final result worth discussing is the response to question 2 asking people whether they considered how a restaurant cooked its food before choosing where to eat out. Sixty-three out of 107 respondents said they did, with the highest yes rates coming from white and Hispanic respondents. Among

those respondents, Hispanics in particular said they considered the cleanliness and hygiene of restaurant kitchens as well as the quality of the ingredients used when choosing where to eat out. Several respondents of different ethnic types said they avoided fried foods and preferred what they perceived as healthier forms of food preparation. With just a few exceptions, the respondents who answered yes to Question 2 did not cite flame cooking as a criteria for choosing where to eat out, a result that again points to an encouraging baseline for electric induction advocates. In other words, as indicated by responses to Question 3, survey respondents did not show any preconceived concern or bias about electric induction cooking. If they did consider restaurant kitchen practices, those concerns focused largely on details other than the type of stove being used. Just as Question 3 showed that respondents did not have any inherent bias against electric induction cooking in restaurants, Question 2 responses showed that respondents did not have any inherent preference or even expectation that restaurants would use flame cooking. This result indicates that with the exception of certain foods that many respondents believed needed flame cooking, electric induction cooking does not trigger any substantial bias or preference at least at the outset.

This research aimed to use the survey instrument to capture the nuances of the larger culinary culture surrounding the use of flame and other fuels to prepare certain types of foods, and the cultural tradition around flame cooking in general. Through these responses, the research sought to tie the topic of public expectations of certain types of food preparation to the rich anthropological literature around food preparation and consumption such as Wrangham's work about flame cooking as well as Oxfeld's and other researchers' work exploring how cultural traditions drive expectations for how certain foods need to be prepared. Longer interviews with respondents about their personal history and experience with specific cuisines would further flesh out this cultural approach to energy transition work, but hopefully this survey instrument provides insight into the culture and values shaping people's expectations and acceptance of electric induction cooking as a replacement for flame as well as other cultural expectations of how restaurants prepare certain foods.

Limitations of Research

This research design was chosen with dual goals in mind - to survey a pool of respondents that reflected California's population, at least in relation to race and ethnicity, and to survey a large enough group of respondents to produce valid and usable results. This survey focused on farmer's markets to achieve these goals with the idea that customers at different farmer's markets across the

Bay Area would come from a diverse and representative enough group of races and ethnicities, especially if they were chosen intentionally for that purpose. Several studies of farmer's market customers across the United States and Canada found that those customers in fact tended to skew female and white with higher than average income and education levels. (Stobbe, 2023). Other studies did not find any conclusive data about farmer's market customer income and education levels although they did also find customers skewed female. (Stobbe, 2023) At the same time, more U.S. government agencies are expanding the use of public food assistance at farmer's markets to promote healthier diets. From 2017 to 2021, redemptions of income-qualified Supplemental Nutrition Assistance Program benefits at U.S. farmer's markets grew by 168 percent, from $22 million to $59 million. (California EBT Office, n.d.) As to be expected, farmer's markets in different locations reflected the demographics of their area. For example, 41 percent of respondents at Oklahoma farmer's markets were college educated, according to one study, while another study found that 62 percent of respondents at New Jersey farmer's markets had a college degree. (Henneberry, 2009; Stobbe, 2023) Income levels of farmer's market customers showed similar diversification in different areas. As another example, the studies found 12 percent of Oklahoma farmer's market customers earned more than $100,000 annually while 27 percent of New Jersey farmer's market customers surveyed earned more than $100,000 annually. (Henneberry, 2009; Stobbe, 2023)

At least based on observation, such income and education diversity likely defined survey respondents in different parts of the Bay Area. Farmer's market customers in the Montclair neighborhood of Oakland conceivably came from wealthier socioeconomic levels than customers surveyed at the farmer's market at the Castro Valley BART parking lot or the Oakland Coliseum Swap Meet. Due to privacy concerns, this survey did not ask respondents about their education or income levels, which limits the applicability of survey data to analyze data based on such factors. This survey attempted to intentionally match respondent demographics with state demographics in relation to gender and ethnicity. Future surveys could also attempt to match respondent demographics with state demographics in relation to education and income levels.

Another limitation of this research is its confinement to the Bay Area in an attempt to capture preferences statewide. While the survey's ultimate demographic breakdown matches gender and racial compositions statewide, this sample within the Bay Area may represent an oversampling or undersampling of those racial and gender groups within the Bay Area itself. This research was limited to the Bay Area due to time and resource constraints. For a state as geographically and demographically large as California, trying to capture a representative picture through surveys would require a significant investment in travel and time. This research attempted to paint that statewide

representative picture through selective interviews conducted in the Bay Area. Future surveys could expand the respondent pool to include communities in Southern California, the Central Valley, and more areas of Northern California.

Doing that would also increase the sample size of this survey, which would arguably produce more representative results. That said, the current sample size exceeds the number of respondents recommended by studies cited by Vasileiou et al. examining the data saturation point for interview-based studies. This survey employed a method somewhere between a public opinion poll and an interview with some of the more open-ended questions encouraging reflection and elaboration from respondents. As described already, the interviews took anywhere from about two minutes to 10 minutes to complete depending on the volume of thoughts shared by the respondents. As one point of reference, the results of this survey did not change significantly after the sample size exceeded 50 respondents, suggesting the data saturation point referenced by the Vasileiou et al. study may have been reached by then. (Vasileiou et al., 2018) As the Vasileiou et al. study points out, sample size is often determined by practical constraints such as the time and resources available for conducting interviews. At least optically, larger sample sizes offer the impression of greater result validity. In practice, beyond a certain point, larger sample sizes may not meaningfully change survey results enough to justify the additional time and resources required to achieve them.

Taking all these limitations into account, this research produces results that should be applicable to restaurants across California in at least gleaning the culinary preferences and the receptivity to electric induction cooking of certain ethnic and racial groups as well as of customers as a whole. The geographic scope and range of questions employed by this research could be expanded to examine possible implications for different socioeconomic groups as well as for specific areas of California. But within the scope set for this research, and given the clear majority opinions reflected across racial and ethnic groups for certain questions in this survey, this research should contribute applicable insights for restaurant owners and policymakers attempting to gauge the receptivity of customers to new electricity-powered cooking methods in general and for specific dishes. As mentioned earlier, little or even no research has previously attempted to measure these attitudes among restaurant customers. This research fills that gap by at a minimum pointing to clear trends within the respondent group here and suggesting directions for future research into this subject.

Chapter 2: The Kitchen as Cultural Space

Theoretical Background

Commercial Kitchens as a Social Space

A commercial kitchen is many things. First of all, it's a place of business where high-volume food preparation is designed to meet the daily rhythms of consumer demand. To that end, the kitchen environment is defined by the economic realities of running a competitive business with low profit margins - factors such as operating costs, capital expenditures, labor retention, customer preferences, advertising, and other bottom line considerations. That reality cannot be overstated. A restaurant that does not earn a profit will not remain a restaurant for very long, and any attempt to understand what makes restaurants tick must keep that economic background always in mind.

Yet beyond that economic truth, a commercial kitchen is also a dynamic conglomeration of professional expertise where employees contribute their specific experiences and skills to produce the best possible food and dining experience, and to help the restaurant draw customers and turn a profit. In other words, the commercial kitchen is a society unto itself where roles are assigned, hierarchies are enforced, and traditions are passed down from employee to employee. Staff learn such best practices from diverse venues such as cooking schools, past restaurants where employees worked, family members, and of course from their coworkers. Chief among these best practices are how to use hardware such as stoves and deep fryers.

Seen in this light, commercial kitchens are in fact a microcosm of society where financial, cultural, and physical forces determine how kitchen staff work with each other using the tools available to them to meet the business' bottom line needs. The challenge in understanding these inherently social dynamics, at least based on the existing literature, is that past research has not cohesively examined these trends in the context of commercial kitchens. In particular, when it comes to studying behavioral dynamics within the social world of commercial kitchens, existing literature is virtually silent. This research aims to fill that gap by arguing that studying such commercial kitchen behavioral dynamics is worthwhile in the context of kitchen electrification because how kitchen employees move in restaurant kitchens, use their tools, and interact with staff reflects inherited knowledge and practices passed down from the restaurant industry's culture at large. All this adds up to what one could call restaurant or kitchen culture. Such cultures are often unique to restaurants as a whole, and even to each restaurant specifically.

Disrupting such cultures with the introduction of new technologies and practices comes with existential risk. The existing cultures have helped the restaurant survive for years if not decades already. Encouraging kitchen staff to learn new practices - a new culture – can risk the very survival of the restaurant itself especially if the new practices disrupt how kitchen staff have long operated. That's why studying the kitchen culture first is a good first step for any effort to alter it. An honest examination of commercial kitchen culture and practices can reveal existing belief systems and traditions that have sustained that kitchen and that may need to change with the adoption of new methods and technologies. Again, this research aims to discover the cultural traditions within restaurant kitchens that staff learn from others and practice as an often unconscious re-enactment of learned culture. This research argues that kitchen workplace culture needs to be understood to appreciate the scale of changes that kitchen electrification will demand from workers.

Social Dynamics and Domestic Technology Adoption

The history of domestic technology adoption may not provide a specific parallel to commercial kitchen technology adoption, but it does inform this research, as described in Cowan's book *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave*. In particular, Cowan explores the push and pull between the introduction of new domestic technology into U.S. households and the social-familial contexts in which the technology is introduced, and how the new technology changes who is expected to take care of the housework. (Cowan, 1983) In particular, social and moral expectations can serve as a constraint on domestic technology adoption especially if the technology and its design don't address the actual needs of households and how family members cook, clean, and run their households. This work argues that social norms such as accepted restaurant industry practices, expectations at that particular restaurant, culinary traditions from which the particular food comes from, and other values form the social milieu in which induction cooktop technology is introduced. To this point, Cowan writes:

> *Thus the history of housework cannot properly be understood without the history (which is separate) of the implements with which it is done - and vice versa. The relation is reciprocal, perhaps even dialectic. Tools have set limits on what could be done in households, but inventors have repeatedly broken through those limits by fashioning new tools. The tools have reorganized the work process, creating new needs, for which some people have attempted to provide new tools - and so on. What makes the history of household technology separate and distinguishable from the history of housework is the existence of social institutions that mediate the*

availability of tools to households. … Just as the history of industrialization cannot properly be written without the history of housework, so the history of household technology cannot be written without the history of the social and economic institutions that have affected the character and the availability of the tools with which housework is done. (Cowan, 1983)

Cowan also identifies what she calls "the work process" - the interconnected system of diverse tasks that help any system function, whether it's a private home or a commercial business. She writes:

The concept of work process reminds us that housework (indeed, all work) is a series not simply of definable tasks but of definable tasks that are necessarily linked to one another: you cannot cook without an energy source, and you cannot launder without water. This concept also becomes important when we try to discover whether industrialization has made housework easier. We must ask not only whether one activity has been altered, but also whether the chain in which that activity is a link has been transformed. (Cowan, 1983)

This "work process" concept is fundamental to this chapter. As this section will show, kitchen staff participate in an elaborate regimented work practice in which each employee must constantly juggle multiple distinct tasks that in the end transform a disparate collection of raw ingredients into an elaborate dish served to the paying customer just minutes later. Those tasks are meticulously sequenced, and at any moment, the tasks occur synchronously for different dishes in different stages of preparation. That means that any modification of a step in the process - such as adopting a different method for cooking the ingredients - necessarily impacts the other steps in the work process. In fact, the heat transfer step of the work process has specific timing constraints that then determine the sequencing of other steps of the work process. The cooking step is in this way the defining engine of the commercial kitchen food preparation system. With that statement taken as a given, this chapter aims to illuminate how kitchen electrification might change commercial kitchen work practices and why those same work processes may prove to be an obstacle to commercial kitchen electrification at least for employees working within the articulated society of a specific restaurant kitchen.

On that final point, Cowan emphasizes how the speed and extent of new domestic technology adoption can be limited by the social values, individual preferences, and other environmental factors in which they're introduced. For example, she argues that a more efficient and equitable strategy for feeding, clothing, and housing families would be through collective living, where the community takes turns cooking, doing the laundry, cleaning the living space, and performing other household tasks. The introduction of refrigerators, washing machines, vacuum cleaners and other domestic technologies certainly makes

such large-scale cooking and cleaning a distinct possibility and offers an opportunity to relieve family members - and in particular, women - from the grind of daily housework. However, at least in the U.S., such collective households have never taken off at any scale because they clash with fundamental expectations Americans have about how families live and care for one another. (Cowan, 1983)

On this topic, Cowan writes about such collective living:

> *The common condition that underlies their failure is the fact that most people prefer to live in their own homes, with their own relatives, rearing their own children, regularly sitting down to meals together, decorating their quarters according to their own lights, dressing themselves according to their own tastes, and controlling the tools with which they have do their work. When push comes to shove, most people will opt to increase the possibility of exercising their right to privacy and autonomy, so that they can sleep, eat, have sexual relations, discipline their children, clean their bodies and their clothes without interference, and so that they can construct long-term emotional relationships with people of their own choosing. And when further push comes to further shove, when decisions have to be made about spending limited funds, most people will still opt for privacy and autonomy over technical efficiency and community interest. … The allocation of housework to women is, as we have seen, a social convention which developed during the nineteenth century because of a specific set of material and cultural conditions. It is a convention so deeply embedded in our individual and collective consciousnesses that even the profound changes wrought by the twentieth century have not yet shaken it. (Cowan, 1983)*

In his work *The Logic of Practice*, French sociologist Pierre Bourdieu offered a broader concept for what might contain the idea of "work process" in what he termed *habitus*:

> *The conditionings associated with a particular class of conditions of existence produce habitus, systems of durable, transposable dispositions, structured structures predisposed to function as structuring structures, that is, as principles which generate and organize practices and representations that can be objectively adopted to their outcomes without presupposing a conscious aiming at ends or an express mastery of the operations necessary in order to attain them. (Bourdieu, 1980)*

Bourdeau emphasized the role of past practices and history in creating *habitus* in this way:

> *The habitus - embodied history, internalized as a second nature and so forgotten as history – is the active presence of the whole past of which it is the product. As such, it is what gives practices their relative autonomy with respect to external determinations of the immediate present. This autonomy is that of the past, enacted and acting, which, functioning as accumulated capital, produces history on the basis of history and so ensures the permanence in change that makes the individual agent a world within the world. The habitus is a spontaneity without consciousness or will… (Bourdieu, 1980)*

In Bourdieu's description, *habitus* also is created from the surrounding environment as it "tends to protect itself from crises and critical challenges by providing itself with a milieu to which it is as pre-adapted as possible, that is, a relatively constant universe of situations tending to reinforce its dispositions by offering the market most favourable to its products." (Bourdieu, 1980)

Working within these concepts, commercial kitchen employees could be said to be operating within their own *habitus* defined by environment and history and generating their own unique but unconscious sets of practices and representations. Taken further, Bourdieu's concept might posit that what Cowan describes as "work process" is inhabited spontaneously by the individual as lived knowledge and culture.

Translating this to commercial kitchens, policymakers hoping to introduce induction technology into more restaurants must take into account the social conventions and values of restaurant owners, their staff, and consumers if they hope to scale commercial kitchen adoption of such electric induction technology – or the *habitus* unique to commercial kitchens. Even if induction cooktops are more efficient and environmentally friendly, they will meet resistance if longtime industry expectations and practices are challenged too quickly and if the norms within the society of the commercial kitchen are ignored. The ultimate goal of this research is to help inform government building decarbonization policy, but the immediate aim of this research is to understand the conventions and expectations generated by decades of commercial kitchen gas-powered cooking use as well as the person-to-person transmission of kitchen culture expectations and rules. Capturing that perspective alone - and identifying the work process of the flame-based restaurant kitchen - would fill a sizable knowledge gap in the current debate over building electrification where the inner-workings of commercial kitchens are largely a black box.

Body Memory in Commercial Kitchens

A common argument used by electric cooking advocates is that cooks resist the transition to induction stoves due to lack of knowledge about the latest

electric cooking technology, and that once they try induction stovetops, they will realize the technology is superior to gas-powered stoves and make the switch en masse. As stated by a publicly available public outreach grant proposal submitted by the Building Decarbonization Coalition, an advocacy organization lobbying for more building electrification mandates and incentives:

> *We believe that promoting greater public awareness of the advantages of high efficiency induction cooking over natural gas is, therefore, a crucial component of an overall building electrification and decarbonization strategy. This greater public awareness combined with the coming price increases of natural gas infrastructure and the movement towards all-electric life-styles powered by renewable energy we believe can begin to move purchasing decisions and build opportunities to disconnect from the gas network. (Building Decarbonization Coalition, 2022)*

This argument essentially assumes that A. the problem is that restaurant owners aren't aware of the benefits of induction stovetops, B. that restaurants can freely choose to adopt the new induction cooking equipment if they want to and if natural gas and renewable electricity prices cooperate, and C. that once restaurants try the technology they will be convinced of its superiority to gas-powered cooking. This chapter tests this argument, in particular component C, by learning more about how flame cooking is actually experienced in the daily operations of commercial kitchens and determining what that lived experience says about the ease of transitioning to induction stovetops.

This chapter seeks to understand what comprises inherited culture within commercial kitchens as defined by the sequence of routines and responsibilities that help such kitchens operate efficiently and profitably. Understanding such kitchen protocols could help illuminate the "work processes" that restaurant employees learn and exercise as members of their restaurant's team. In particular, this research will explore the "work process" concept as expressed through the body memory of kitchen employees - that is, how kitchen employees internalize their inherited culture, which guides how they physically work in their kitchens. French theorist Marcel Mauss posited that people expressed their group identity and culture through how they walked, sat, swam, or danced (Mauss, 1973). As Mauss conceived it, culture is so ingrained in humans, it even guides people's unconscious everyday movements. This idea complements the concept of *habitus* described previously – unconscious structures determined by history and environment that people embody in specific times and places. (Bourdieu, 1980) Commercial kitchens are, if anything, places of action, and if an observer seeks to understand the culture of such kitchens, studying how kitchen employees physically move in their workplaces – or their *habitus* - to deliver a delicious plate of food is a great place to start.

A caveat is that Mauss' body memory concept was rooted in national identity, as in a French or Peruvian way to walk, swim, or even to make love, that is largely absorbed from growing up in that culture rather than actually passed down and taught and learned. (Mauss, 1973) What occurs in commercial kitchens and is often passed down among established staff members and managers to rookie staff and doesn't necessarily reflect a national way of doing things. That said, through this research, it became clear there *is* a national style of cooking for certain cuisines regardless of whether it's learned from osmosis or actively taught to staff members. Just as Chinese cooks use the all-purpose cleaver as their French chef, cleaver, or paring knife in one package, or as Mexican cooks quickly learn how to grind and roll tortillas and then brown them on a grill, national cuisines are distinct ways of doing the same thing. For the purposes of this research, how body memory is learned and passed down will be considered a difference without a clear distinction.

Research Project 2: Rhythm and Body Memory in Gas-Based Kitchens

Project Overview

This research uses participant observation methods to record the rhythms and work practices of kitchen staff in several restaurants around California with the aim of describing the body-based "work process" of each restaurant. This research uses this approach to explore whether induction cooking may fit into existing commercial kitchen practices or if staff retraining and other modification would be needed with the introduction of induction stovetops. This question speaks to the business case for commercial kitchen electrification as retraining staff means potentially halting restaurant operations and devoting resources to teaching staff how to use induction stovetops in high-volume business settings. Answering that question means first describing current kitchen practices designed around the rhythms of flame-based cooking.

Objectives

This research aims to illuminate how staff in current natural gas-powered commercial kitchens incorporate flame-based cooking such as grilling and roasting into their minute-by-minute work routines. This research also aims to more broadly capture the sense of rhythm and interconnectedness in commercial kitchens as each employee fulfills their own task, which follows from and leads into the tasks of their colleagues. This kitchen work flow schema could help answer how the introduction of electric induction cooking would impact the existing processes in natural gas-powered commercial kitchens. This research would then aim to use this workflow schema, or "work process" as Cowan defines it, to help define restaurant kitchen culture writ large. Ultimately,

this definition could help determine the compatibility of electric induction technology within existing commercial kitchen culture and the ways kitchen staff express their culinary culture and training through their physical actions and work rhythms.

Referring to the California Restaurant Association lawsuit against the City of Berkeley, this research addresses its contention that "[m]any chefs are trained using natural gas stoves, and losing natural gas will slow down the process of cooking, reduce a chef's control over the amount and intensity of heat, and affect the manner and flavor of food preparation." (California Restaurant Association, 2019) This research tests the association's linking of chef training with natural gas use and explores how any such relationship expresses itself in commercial kitchens.

Methods

The methods used in this research reflect the limits encountered early on while attempting to understand restaurant kitchen protocols and the resulting compromises that were made to produce meaningful observations of commercial kitchens. The initial plan for this chapter proposed observing a commercial kitchen with the full participation of the restaurant staff as well as possibly volunteering as a line cook to gain knowledge about the lived experience of kitchen operations. Eight restaurants in the East Bay, however, did not accept offers of free labor made via email and in person from February 28 and May 1, 2022 in response to online advertisements seeking line cooks. Similarly, a personal introduction to the manager of a downtown Berkeley bar and grill did not help to even passively observe the kitchen's operations. The manager of a newly opened upscale Thai restaurant in Oakland's Laurel neighborhood explained that she ran a small staff and couldn't spare the time to train a researcher for a temporary assignment. That experience highlighted the high-pressure environment of restaurant kitchens where a newcomer needing training is a significant burden - and an unwelcome burden if that newcomer is only planning to work for a few months.

As an alternative way forward, the research narrowed its scope to four East Bay restaurants with open kitchens visible from the dining area – Bongo Burger, a student-centered fast food restaurant at Dwight Way and Telegraph Avenue in Berkeley; Noodles Fresh, a mid-priced Chinese restaurant in Berkeley; Trabocco Kitchen and Cocktails, a mid-priced, popular Italian restaurant in the South Shore shopping center in Alameda; and C Casa taqueria, a mid-priced Mexican restaurant in the Public Market food court in Emeryville. This research at C Casa, Bongo Burger, and Trabocco required observing kitchen staff without their knowledge or permission at the restaurants eight times in March and April 2022, with each observation lasting about an hour. Five observation sessions were conducted at C Casa (observation start times were 1:25 pm Saturday

March 12, 2022, 2:07 pm Sunday March 20, 2022, 6:42 pm Wednesday March 30, 2022, 1:46 pm Saturday April 9, 2022, 6 pm Sunday April 24, 2022), two at Bongo Burger (one starting at 12 pm Saturday March 5, 2022 and one starting at 11:21 am Tuesday March 8, 2022), and one at Trabocco starting at 4:17 pm on Saturday March 5, 2022. Observations were conducted of the kitchen at Noodles Fresh at 5:30 pm Saturday February 17, 2024 and 2:30 pm Friday March 7, 2025 with the knowledge and participation of the restaurant's co-owner, who also spoke about her experience using induction stove tops at her home and in her restaurants.

Of the three restaurants, C Casa is the most proactive in promoting their use of grilling in their menus and on their website. In 2022, the restaurant used the marketing tag line "Reimagined Mexican Food" on its website, and its higher-priced menu reflected a fusion of traditional Mexican ingredients such as grilled chicken and beef with modern health-conscious American ingredients such as crumbled blue cheese and lime-cumin vinaigrette. (C Casa, n.d.) The restaurant also offered an extensive vegan menu and emphasized its fresh produce and pasture-raised beef as part of its promotional materials (C Casa, n.d.).

Visually, C Casa's dishes make an impression with the quantity of food offered and the amount of vegetables included in each taco, looking more like a mini-salad than the typical grilled meat wrapped in a tortilla. A grilled angus steak taco, for example, measured about seven inches in diameter, with the steak strips buried in a mound of lettuce, grilled onions, avocado, peppers, and blue cheese. The menu also included a duck confit taco, a Dungeness crab taco, and a vegan seven-layer dip and chips. The business has outlets in Emeryville, Napa and San Ramon. (C Casa, n.d.)

From March 12 to April 24, 2022, observations were made at C Casa five times both during lunch and dinner periods, as well as during morning set-up and nighttime closing times. Kitchen staff did not know they were being observed, and the observer did not attempt to speak to them until April 9 when he informed the cashier of his research and proposed interviewing the staff as well as the owner about their use of flame-powered cooking. The cashier directed the observer to contact the restaurant owner by email. The restaurant did not respond to interview requests made by email.

Bongo Burger has three locations near the UC Berkeley campus primarily serving students and those living near the university. Its menu offers staples of American fast food such as burgers and fries as well as a large selection of Mediterranean and Middle Eastern fare such as falafel, grilled lamb sandwiches, and shish kabob sandwiches and plates. (Bongo Burger, n.d.) A flame grill anchors the kitchen at each of the three restaurants along with a deep-fryer

and a griddle. Observations were made of the kitchen from the dining room of Bongo Burger on March 5, 2022 and March 8, 2022. The kitchen staff were not informed that they were being observed.

Trabocco operates a large restaurant in a popular Alameda outdoor shopping center with both indoor and outdoor seating areas built around an open kitchen featuring flame-based stove burners, a flame grill, and a wood-fired oven. The menu offers salads, pizzas, pastas, and grilled meats and seafood, with the menu descriptions emphasizing the grilled and wood-fired dishes. (Trabocco, n.d.) One observation was made of the kitchen from the Trabocco dining room in the afternoon of March 5, 2022. As with the other two restaurants, the kitchen staff were not informed that they were being observed.

Noodles Fresh operates two restaurants in El Cerrito and Berkeley serving a wide range of Chinese dishes such as noodle soups, noodle plates, rice plates, and stir-fried dishes such as Mongolian Beef and Kung Pao Chicken. (Noodles Fresh, n.d.) Cooking in the kitchen is conducted almost exclusively in woks over high flame with the same wok quickly rinsed and used for repeated dishes. The restaurant co-owner spoke about her kitchens' operations during a phone interview on February 3, 2024 and during an in-person interview on February 17, 2024. In-person observations of the kitchen were conducted on February 17, 2024 and March 7, 2025 with the knowledge of the kitchen employees.

Contributions to Literature

This research contributes a rare in-the-kitchen perspective to the current electrification literature, which has so far been largely focused on the engineering and environmental impacts of residential electrification. This research leverages theoretical work examining the idea of body memory as described by theorist Marcel Mauss and applies that to the commercial kitchen setting. By doing so, this research provides a novel lens through which to view work within restaurant kitchens - one that may help illuminate how restaurant staff will need to physically adapt to the new rhythms and requirements of electric induction cooking. This research also adds an intentionally practical side to the electrification literature by providing a detailed account of how kitchen staff work in restaurants and how electric induction stoves may integrate with or disrupt that work flow. This work argues that such knowledge is important to understanding whether restaurants accept or reject electric induction technology and how electrification incentives could be better designed with current commercial kitchen practices in mind.

Mauss' seminal work "Techniques of the Body" focused on how national and ethnic identities determined how people underwent everyday activities such as walking and swimming. (Mauss, 1973) Similarly, Bourdieu's work discusses

the role of *habitus* in guiding behavior in specific times and places, so that that behavior expresses the history of the practitioner and the larger culture the behavior takes places in. This chapter applies that perspective to the workplace since work activities can be repetitive and integrated into a person's unconscious body memory from the sheer amount of repetition involved, especially in more physically demanding workplaces such as restaurant kitchens. While this variety of body memory doesn't hinge as much on national or ethnic identity, it still expresses a distinct culture, or perhaps a microculture as it exists within the restaurant industry or even in a specific restaurant's kitchen. This chapter thus expands on Mauss' concept of body memory from an expression of national identity to include other forms of identity such as one's professional identity within a unique workplace and one's physical approach to preparing and serving food. This chapter also expands on Bourdieu's *habitus* concept as embodying the history and traditions of a particular workplace as well as the larger industry and even national culture that restaurant workers have learned their craft and built their careers in.

Finally, this chapter builds on the work of Cowan in analyzing how new domestic technologies are incorporated into settings such as household or restaurant kitchens, and how those new technologies impact hierarchies and other social dynamics observed in those settings. The common concept here is the view of workspaces as distinct social systems that are shaped by the tools people use in those spaces. While this chapter doesn't directly address the introduction of a new technology into commercial kitchens, it details how the current restaurant workplace uses existing kitchen technology and how that technology may dictate dynamics such as body memory-informed work processes. The aim of this chapter is to produce new understandings of workplace technology adoption as explored by Cowan that are specific to commercial kitchens.

Results

Despite the method limitations of this research, this research still was able to obtain helpful insights by observing the kitchens of Bongo Burger, Trabocco Kitchen, and C Casa from public dining areas, without interviewing restaurant staff or otherwise interacting with restaurant employees, as well as by observing the staff of Noodles Fresh with the restaurant owner and staff's consent. This chapter will focus on C Casa's kitchen as the majority of observations were made there producing the bulk of this research's applicable insights, but the observations made at the other three restaurants also provided helpful insights that complement the findings made at C Casa.

C Casa's kitchen was divided into two halves: the cooking area with a flame grill, griddle, conventional ovens, rotisserie oven, and deep fryer, and a

prep and finishing area where avocado, cheese, peppers, and other toppings were added to tacos and other dishes after meats and vegetables were grilled and place atop tortillas. Male employees worked exclusively in the cooking area, while female and male employees worked in the food finishing area, mirroring the gender composition of the kitchens at Bongo Burger and Trabocco. During the observation periods at C Casa, a younger man did almost all of the cooking although an older male employee would occasionally take over the grill when the younger cook was taking a break or otherwise busy elsewhere in the kitchen.



Figure 3: Cook at C Casa Taqueria in Emeryville juggling several different tasks at the same time on March 12, 2022.

The tortilla press and grill were arguably the most visible parts of the kitchen, placed against the glass divider on the busiest side of the restaurant near the main entrance. The tortilla press and grill were conceivably placed in that location as an advertisement for the restaurant's authenticity and made-from-scratch aesthetic, a selling point made visibly by the restaurant's website with its emphasis on "pasture raised," "all natural," and "fresh daily" ingredients. Such claims to freshness could be seen as part of C Casa's argument for it charging higher prices than other taquerias serving the same foods, as documented in Chapter 1. In that light, the tortilla press is presented to the public as visible evidence for that freshness and quality. The flame grill and broiler also situated on the busier side of the restaurant could be playing the

same function as the tortilla press, as evidence of the restaurant's authenticity and quality.

The heat-focused half of C Casa's kitchen involved several types of cooking as demonstrated by this Figure 4.

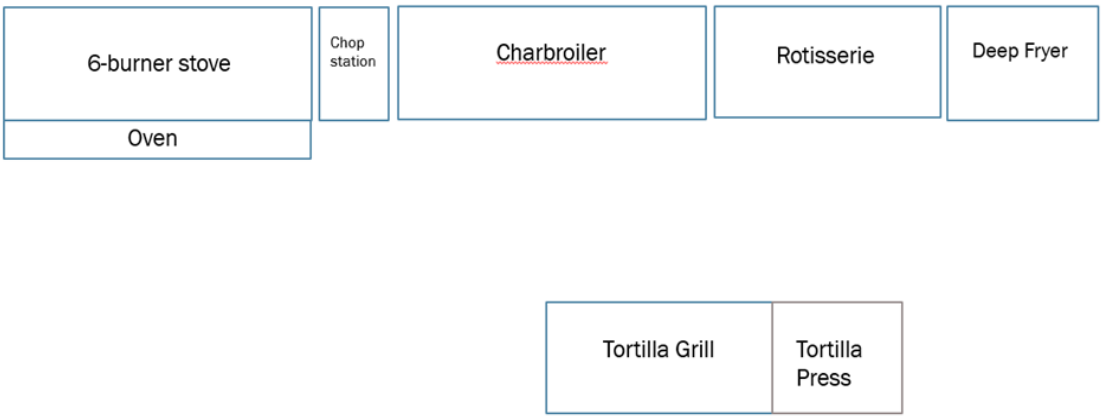


Figure 4: Kitchen layout of C Casa Taqueria in Emeryville, California in April 2022.

At least three of these cooking types would appear to require flame – and therefore, gas-powered heat: the 6-burner stove, the charbroiler, and the rotisserie oven. The conventional oven, deep fryer, and tortilla grill depended on heat rather than flame and could conceivably be replaced by an electricity-powered alternative. The cook at C Casa would typically grill steak, chicken, and other meats on the charbroiler while frying onions, vegetables, and meat in a pan on the stove. While pan-frying, the cook would often toss the ingredients as a final flourish that would send flame leaping about a foot over the pan. This same flame-leaping flourish was observed in the kitchens of Bongo Burger and Trabocco, raising the question of whether it served any practical purpose in the preparation of dishes or whether it was meant more for dramatic effect. The co-owner of Noodles Fresh answered this question at least in the context of Chinese food by stressing the importance of flash frying ingredients in high heat at the end of the process to create a crispy outer shell especially for meats and seal in the juices within. The male cook observed working the wok at Noodles Fresh made the same tossing flourish to finish each dish with flames leaping over the wok.

In all the restaurants observed, it was clear that grilling or otherwise heating food was just one activity among several tasks that consumed the cook's time. At C Casa, the cook also was in charge of pressing and grilling tortillas, tending to whole chickens cooking in the rotisserie oven, watching over the pot of beans perpetually simmering on the stove, chopping meats and vegetables, baking enchiladas in the oven, cooking vegetables and meats on a

pan over the flame stove, deep-frying tortilla chips or other foods, and scraping and cleaning the grill. At closing time, the cook also performed cleaning tasks such as scraping and cleaning the tortilla grill, wiping down the chopping area, tortilla press, and stovetop, and stowing the washed pots and pans. Work rhythm was essential to this routine. The cook never stood still or waited for food to finish cooking but instead appeared to sense how long each cooking task would take and how many other tasks he could work in during the interim. His actions in the kitchen resembled a dance between the diverse cooking tasks with the performance resulting in plate after plate of cooked meats, vegetables, and other dishes passed onto the finishing half of the kitchen to be completed for serving.

This pattern mirrored cooking practices observed at Bongo Burger, where the head chef juggled various types of cooking tasks – grilling, deep frying, chopping onions – along with serving as a kind of security guard scanning the dining room for any potential safety issues from customers. See Figure 5.



Figure 5: Kitchen layout of Bongo Burger on Dwight Avenue in Berkeley in November 2024.

At Trabocco's much bigger kitchen, work was more specialized with the stove cooks not as much involved in chopping or otherwise preparing foods but still constantly sauteing, grilling, and cooking foods - part of the restaurant's high volume dinner rush. See Figure 6. The cooks at Trabocco also engaged in multiple kitchen tasks at the same time involving the stove, griddle, convection oven, and wood-fired pizza oven. Consistent throughout the different restaurants was this intricately timed dance among a range of heat sources, with the cook often visually reading from the level of flame on the stove or griddle how long the food needed to cook to be completed and how long they had to complete another task in the kitchen.

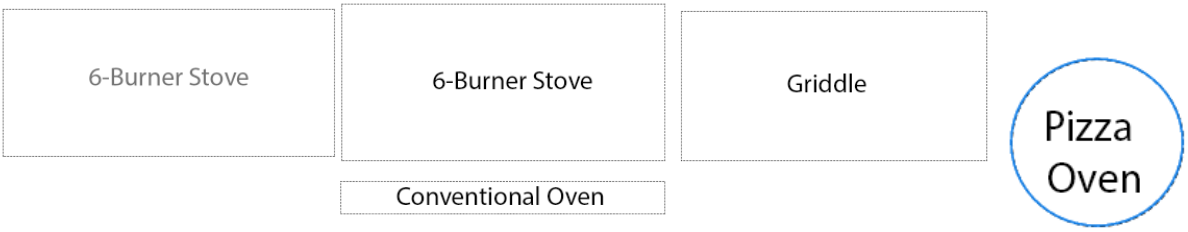


Figure 6: Kitchen layout of Trabocco in the South Shore Center in Alameda in November 2024.

At Noodles Fresh, the cook performed an array of tasks with only two tools, the wok and a ladle. See Figure 7. As observed on March 8, 2025, the cook controlled the intense gas-powered flame with a foot pedal and cooked the ingredients with such powerful heat that he would flash-fry foods for only a couple of seconds before ladling the finished product to a to-go container or plate. Similarly, the cook was able to boil water within 10 seconds in the same work over jet engine-intense flame. The cook would also shake the giant metal wok with his bare hands, which were sometimes protected with a dish towel but often not. Hot oil and other ingredients would splash on his hands and arms as he worked, and the flame would often leap across the wok to his fingers. Finally, the cook would rinse out the wok on that same stove using a wooden brush in preparation for the next dish and then dump the dishwater in an ever-present pool surrounding the wok and the flame. The whole process was based fundamentally on cooking over blasts of heat and fire that quickly prepared the dishes to produce what is known as *wok hei* flavor, or a smoky quality distinguished by a crispy exterior and a softer savory interior to meats and vegetables.

The Noodles Fresh chef cooked in a clearly distinct way compared to the other restaurants observed as part of this research, and it can be argued that this style of cooking expressed a kind of culinary culture in action. Other Chinese restaurants have long used the same method of wok cooking with ladle and intense flame to produce the same type of *wok hei* flavor as documented in Kenji López-Alt's definitive book *The Wok: Recipes and Techniques*. (López-Alt, 2022) As López-Alt writes, this unique dance of flash-frying on the wok over high flame derives from a distinct Chinese culinary tradition.

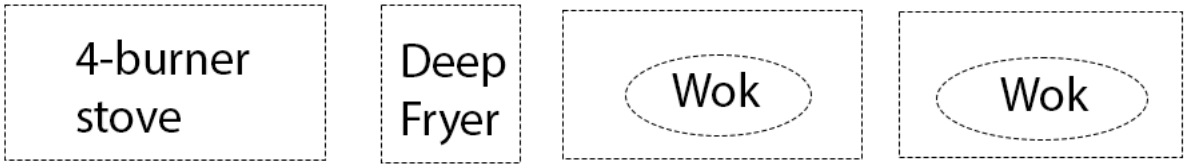


Figure 7: Kitchen layout of Noodles Fresh in Berkeley in November 2024.

At each restaurant, the kitchen work flow followed more than one timeline with different dishes at different stages of preparation at any one time using different types of heat sources. Yes, heat fueled the whole operation, but time provided the structure. The kitchen staff appeared to internalize the timing of each dish and move to the next step of preparation at just the right time, whether it meant flipping the chicken on the grill or tossing the wok full of pork and vegetables so that the flame leaped over the wok. These actions spoke of a work process that had become second nature for the staff, less mental than physical, with an internal timer feeling the tick of each step of the process.

Inherited Techniques

This body-based kind of knowledge appeared to reflect the cooks' experience and familiarity with the kitchen, the kind of lived experience of doing the same work day in and day out. That knowledge may also have resulted from social elements such as the larger culture of that restaurant and of the restaurant industry in general. In "Techniques of the Body," Mauss describes "a series of assembled actions, and assembled for the individual not by himself alone but by all his education, by the whole society to which he belongs, in the place he occupies in it." (Mauss, 1973) Similarly, the cooks' bodily familiarity in the kitchen may have reflected more than a personal adaptation to the kitchen. It could have represented a larger inheritance from their national culture or perhaps from a universal kitchen culture that is passed on from cook to cook. Mauss details the culture-specific ways people eat and drink, which might naturally translate into culture-specific methods of food preparation. (Mauss, 1973) At C Casa, an older employee occasionally offered the younger head cook what appeared to be lessons on food preparation, hinting at an inter-kitchen transmission of collective experience and knowledge.

This lived experience and kitchen culture may also inform restaurant employees' expectations of kitchen cooking technology and ways to prepare specific foods. As Darby writes, lived experience is inherently locational – it reflects the experience of this specific kitchen in this specific geographic location, in addition to whatever culture and traditions the cooks inherit from their ethnic culture or the universal culture of the kitchen.

Darby writes:

> *Gas and electricity may be the same in any place, but they are not bought, used and understood in the same way in any place: housing, climate, demographics and social networks, all place-specific, are important in influencing how energy is captured and used. All these considerations make it clear that energy transition is more than a*

sequence of developments during which average people in average buildings meekly and unproblematically adopt new technologies and adapt to new infrastructures. (Darby, 2017)

With that locational nuance in mind, one overarching conclusion I made about C Casa was that flame is an essential part of its kitchen as it is currently set up. The menu highlights the flame-cooked nature of the foods in the names of several dishes: "Rotisserie Chicken and Cheese Taquitos," "Grilled Angus Steak Tacos," "Grilled Prawn Tacos," and "Grilled Atlantic Salmon Taco." (C Casa, n.d.) As Harold McGee writes in *On Food and Cooking*, grilling meat directly over flame, red-hot coals, or even an electrical heat source or broiling meat in a pan under a heat source at high temperatures browns the meat, creating a crust with a juicy interior underneath. (McGee, 1984) Current induction stove technology depends on magnetic energy heating a pan or pot; it does not offer any alternative to flame-grilling of meats or of preparing foods in rotisserie ovens so at the very least, the names of the dishes would need to be changed if this kitchen switched to induction cooking. The placement of words such as "grilled" or "rotisserie" at the beginning of the dish names, however, suggests that these descriptors are considered important elements of the dishes' identities and that the restaurant believes its customers will order those dishes because they are cooked with flame.

A larger question is whether frying angus steak or prawns in a pan heated with an induction stovetop fundamentally changes the identity of the dishes and thus changes the identity of the menu, and of the restaurant itself. If so, this is a pivotal question for any business such as a restaurant working with a thin profit margin that has carefully curated its menu and brand based on the perceived preferences of its customers. This question lies at the heart of the electric kitchen debate, whether flame cooking is essential to the identity of certain foods and of the restaurants that prepare them. As McGee's book suggests, at least with grilled meats, induction stoves are at this point not an adequate substitute for producing the browning texture and smoky taste that many people associate with such dishes. (McGee, 1984) So at least for C Casa, which has built its menu around the allures of grilling, the answer is yes, cooking with flame appears to be a fundamental part of the restaurant's identity.

This question has become especially relevant for Chinese restaurants, many of whom use intense flame to flash cook food in woks. The California Restaurant Association's lawsuit against the city of Berkeley's gas infrastructure ban specifically mentions "the use of intense heat from a flame under a wok" when arguing that "restaurants specializing in international foods so prized in the Bay Area will be unable to prepare many of their specialties without natural gas." (California Restaurant Association, 2019) Building on that line of argument, Southern California Gas Co. and the California Restaurant Association

reportedly recruited Chinese restaurants to defend natural gas-based cooking when the city of Sacramento was considering its own gas infrastructure ban. (Plachta & Rubin, 2023) Part of the restaurants' argument was that the distinct flavor of Chinese foods cooked in woks at high temperatures could not be duplicated on induction stoves due to their inability to reproduce the sudden spikes in heat that flame cooking can supply.

"This is our family's business that we've been in for 84 years, the style of cooking has been around for thousands of years," Kevin Fat, owner of the historic Frank Fat's Chinese restaurant in downtown Sacramento, told The Sacramento Bee. "We felt we needed to protect our culture. We need to protect the way we cook. And that was our only goal in mind." (Plachta & Rubin, 2023)

Two Chinese restaurant owners, one in Marina Del Rey and the other in Berkeley, interviewed as part of this research echoed that sentiment. (Chang, 2022-2024) The first restaurant owner, who had recently sold his business, said his restaurant kept its gas stoves on at high heat throughout the lunch rush period from 11 am to 2 pm every day with woks ready to cook dishes for less than a minute with a splash of cooking oil and prepared ingredients. The restaurant owner said he did not believe induction stoves or even specialty induction woks could serve the same function, no matter how high-end they were. The restaurant owner said he had not tested out induction stoves yet.

Another Chinese restaurant owner in Berkeley, on the other hand, said she was very familiar with induction stoves, having cooked with one for years in her own home kitchen. She said she had also cooked on an induction wok and found that it could not produce the type of heating spikes possible with wok cooking on flame.

Observing the cooks working in her restaurant fleshed out her statements. One Chinese man working with a fellow chef in the kitchen cooked exclusively with a wok heated over intense flame and a ladle, which he used to scoop cooking oil, water, noodles, cut vegetables, meats, and spices into the wok. He would then use his right hand to hold onto the actual hot wok, shake the wok, and raise and lower it over the leaping flame, while he used his left hand to ladle in ingredients. He would ladle in a splash of oil, which would send the flame jumping about a foot over the wok. This was the heat spike that the Chinese restaurant owners touted as giving their dishes their unique singed *wok hei* flavor. The cook then poured the finished dish into a bowl or plate and ladled in hot water to wash the wok right on top of the flame.



Figure 8: Cooking chicken and vegetables in boiling broth to make Jiangxi Noodle Salad in a wok over high flame at the Berkeley restaurant Noodles Fresh on March 7, 2025.

Based on this observation, induction woks are simply not designed to be used in the same way in which the cook was working that afternoon in Berkeley. Principally, due to the interaction of electromagnetic energy created by copper coils under the induction cooktop, steel woks must be in contact with the induction stovetop at all times to generate heat and cook foods. That means the vertical movements used by the cook that afternoon while tossing and stirring the ingredients would result in sudden heat losses, which would extend the cooking time needed to finish the dish and also result in the intermittent heating and cooling of ingredients in the pan. Also, an induction stove cannot produce the final flash of flame used to finish off Chinese dishes since there is no flame involved at all with induction stovetops.

Again, the Chinese restaurant owners, as well as other restaurants interviewed as part of this research, pointed to the ability to produce that spike in heat and flame as an important tool to quickly brown meats and seal in their juices, producing a crispy yet flavorful effect beloved in dishes such as pepper-fried beef and kung pao chicken. Currently, many Chinese restaurants use non-stick Teflon woks due to the demands of repeatedly flash frying foods and then washing the woks on the stove itself throughout the work day. Such non-steel woks simply do not work on induction stovetops because they cannot conduct with the magnetic coils inside the stove.

These findings will be further tested in the kitchen experiments described in Chapter 4, especially regarding the use of the latest generation of induction woks in Chinese restaurants. Again, this research does not suggest solutions for overcoming obstacles identified in commercial kitchen electrification, but understanding how kitchen staff currently work in flame-based kitchens can help restaurants devise new, induction-based cooking methods that minimize the need to retrain employees.

The bottom line is that induction stovetops heat much more quickly than flame stoves do. They also do not offer a visual way for cooks to gauge the heat they are producing at any given time – an important indicator for cooks when they are juggling several elements of the cooking process at the same time. These and other kitchen work process changes introduced by induction stoves will require kitchen staff to relearn much of their current best practices. And what they will be relearning can be called a different kitchen culture, one dictated by the rhythms and idiosyncrasies of induction cooking.

Discussion

This research has both provided several take-away insights about the role of flame cooking in restaurants and pointed to a new array of theoretical questions about the importance of culture in shaping kitchen operations. C Casa's menu, website, and public presentation at the very least highlight the use of grilling in its kitchen, which speaks to the cultural values associated with flame cooking. Flame may be seen as a more authentic manner of cooking and may appeal to a food philosophy that shuns, or at least, looks down on chemically altered ingredients, genetically modified produce and meat, and, perhaps as an extension, what may be seen as artificial food preparation techniques. The culture of diverse consumers plays into this picture, but also the culture of the food preparers. Many of the kitchen workers observed in this research appeared to be Latin American at least in ethnic heritage, so a good follow-up question might be to examine the influence of Latin American values and societies in restaurant kitchens, especially as many people of Latin American heritage fill virtually every type of restaurant kitchen in California. Also, further research could examine how specific Latin American food preparation cultures appear in California kitchens. For example, would the cooking practices of an indigenous town in Guatemala show up in a commercial kitchen in Union City where immigrants from that village worked? If so, how might such employees mix their traditions with the cultures of other workers from other parts of the world in the kitchen? And finally, is there such a thing as a universal restaurant kitchen culture that is passed on from employee to employee, at least in the United States?

Other follow-up questions to this research could explore several strands of research literature examining the economic factors of energy transitions. For example, future research could examine how clean energy technology such as electric vehicles and solar panels are targeted specifically at wealthier households who presumably can afford their initially higher prices and how access to those technologies can be widened. That same economic dynamic is at work in electric kitchens with induction stoves costing around $4,000 a unit compared to less than $700 for a gas-powered stove. (Best Buy, n.d.). Installing an induction stove also requires upgrading electrical systems to higher voltages, which can add up to $4,000 in panel upgrade costs for a single household. (Synapse Energy Economics [Synapse], 2018) Anecdotally, estimates for such residential panel upgrades for household electrification purposes have come in at as much as $15,000 per household. Installing multiple induction stoves as well as convection ovens in a commercial kitchen can easily add up to tens of thousands of dollars in extra costs. Life-cycle analysis of those costs may reveal savings due to lower energy bills in residential buildings, but for a business working with a tight bottom line, high initial capital costs may be the deciding factor in sticking to known and cheaper cooking technology. (Synapse, 2018)

When considering the importance of culture, these high upfront costs skew the market for such technology and in effect stigmatizes induction stoves as luxury items. Writ large, the challenge for the clean energy transition is figuring out how to lower the cost of entry for technologies such as electric vehicles and induction stoves and democratize sustainable culture. If kitchen electrification advocates have their way, every restaurant in the state will eventually be cooking with some form of induction technology. To do that, the technology needs to both be affordable and embraced by restaurant kitchen staff as part of their internal culture. Democratizing access to induction technology will help usher in that cultural acceptance.

This research has emphasized the core value of lived experience in kitchen work and how so much of what occurs in a commercial kitchen involves culture, values, and knowledge operating at the level of instinct. This research connects the idea of lived experience to that of "work process," "body memory," or "habitus" described in previous works in relation to the often unconscious systems of movement and living that people embody in their own spaces and times. Further deconstructing that instinctual knowledge into cultural origins and values could produce an even more detailed understanding of the current resistance among many restaurant and home chefs to induction cooking. This more nuanced understanding of kitchen culture and tradition could also help inform policymakers intent on phasing out methane use in buildings across California. Kitchen culture is the frontline for the cultural shift that needs to happen to catalyze kitchen electrification. Understanding the nuances

of that kitchen culture is an important step to devising ways to help restaurants adapt to this cultural disruption.

Limitations to Research

The original ambitions of this research quickly clashed with the reality of the restaurant industry. Restaurant owners had no time or inclination to train a graduate student to work in the high-intensity, low-margin microcosms of their kitchens. In fact, few restaurant owners wanted to even talk for a few minutes about how their kitchens worked. As a result, this research had to adapt to that attitude by settling for a purely observational approach. The limits to that approach were also immediately apparent: The observer couldn't ask kitchen staff about what was being observed, couldn't clarify any confusions, or ask about the relationships among kitchen employees. Also, instead of spending several months working in a kitchen absorbing the world around him, as originally planned, the researcher could only glean what he could through about a dozen hours of observation from the restaurant's dining spaces.

As it turned out, that approach produced plenty of useful information about the restaurant kitchens included in this study. This research could note repeated cooking practices in the kitchen such as the final toss of the pan as seen in different restaurants and capture the nonstop dancing of staff between diverse back-of-the-counter tasks. When the Noodles Fresh co-owner did agree to participate, she was able to fill in the blanks about some of the kitchen practices observed and provide her own experience cooking on induction stoves. That verbal report, however, didn't add all that much nuance to the information gathered just from watching her staff hard at work during an afternoon lunch rush. Of course, it's hard to tell exactly what kind of insights three months of work in a commercial kitchen would have provided for this work. That surely would have produced another type of chapter. But it appears that the research approach that was ultimately adopted proved to be useful enough to say something new and interesting about how restaurant electrification can impact the work flow and culture within the kitchen.

Future research could try again to spend more time in the kitchen working as part of the team preparing and cooking foods to meet the relentless demand of the lunch or dinner rush. Follow-up research could also examine the work rhythms of one of the small but slowly growing number of all-electric kitchens such as that of Homeroom, a popular macaroni and cheese restaurant in Oakland that uses induction stoves to heat elbow pasta and cheese and cream sauce. One other potential area of research is the mixed-fuel restaurant using both electric induction stoves and some form of flame cooking whether as part of a wood-fired oven or a propane-powered burner. As Cowan has described, the introduction of new kitchen technologies generates new kitchen

cultures, and as induction cooking works its way into more restaurant kitchens, new kitchen cultures are sure to arise. Already, culinary schools are beginning to teach cooking with electric induction equipment to students, which will help introduce the technology to restaurant staff and may begin changing the overall kitchen culture.

Chapter 3: The Economics of Commercial Kitchen Electrification

Financial Challenges

Transitioning millions of buildings across the state to electric-only heating and cooking will require overcoming huge economic obstacles, on top of the cultural challenges described in previous chapters. To start with, most buildings will require expensive electrical system upgrades to provide the higher voltages (240 volts in most cases) required by electric heat pump space and water heaters and induction stovetops. Those appliances themselves cost hundreds if not thousands of dollars more than their methane-based counterparts, although that price gap has been narrowing. On the other hand, using electric heat pump space heaters and induction stovetops can reduce energy bills due to their higher energy efficiencies, especially in hotter areas that require air conditioning. Also, updates to HVAC systems and appliances represent one of the most cost-effective decarbonization methods available compared to more expensive methods such as carbon capture and storage photovoltaic systems. (McKinsey & Co., 2013)

The energy consulting firm Synapse Energy Economics weighed both costs and savings and found in 2018 that the cost difference depended on the amount of air-conditioning needed for a building and whether the building had solar panels. (Synapse, 2018) Although natural gas costs less per unit of energy compared to electricity at least in California, the Synapse study calculated higher energy cost savings for all-electric buildings when consumers ran their appliances at off-peak hours when electricity rates were lowest. Energy cost savings also grew when consumers utilized rooftop solar panels to power their homes and buildings, Synapse found. (Synapse, 2018) Unlike a single-family home, however, a restaurant cannot operate only during off-peak hours if it runs a nightly dinner service. Also, restaurants often are located in multi-purpose commercial buildings so they may not be able to install dedicated solar panels to power their operations.

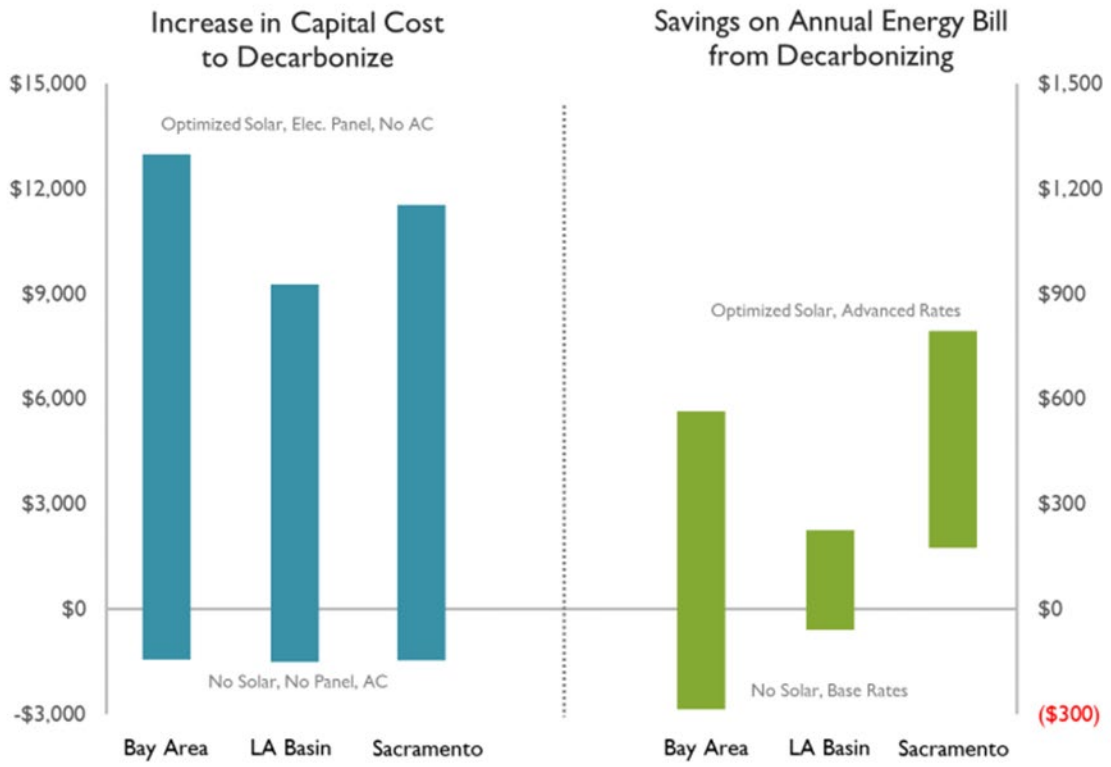


Figure 9: Capital costs of electrifying existing buildings are equivalent in the Bay Area, LA Basin, and Sacramento, but annual energy bills can vary widely depending on location, largely due to different levels of air conditioning use. (Synapse, 2018)

As noted previously, builders would face far fewer financial obstacles if they installed electric space and water heaters and induction stoves in new buildings. In fact, the Synapse report found that in most cases, doing so would actually save developers substantially in capital costs compared to building with natural gas service, especially as the prices of electric heaters and stoves fall. (See Figures 9 and 10) Much of this cost difference comes from not having to install gas infrastructure in buildings as well as not having to buy a separate gas furnace and electric-powered air conditioner since a heat pump unit can provide both heat and cooling. Again, the cost savings are highest in hotter areas where air conditioning is more common and where a heat pump can eliminate the need to buy an air-conditioning unit. (Synapse, 2018) For restaurants that are just opening, moving directly into a new electric kitchen would also help the business avoid having to shut down for weeks in a row to update the building's electrical system and kitchen infrastructure - expensive propositions for such low-profit margin businesses. While encouraging, the overall lower capital cost of new electric buildings is offset by the slow replacement

rate of the state's building stock as well as of gas-powered appliances. For example, the average home in California has a 75-year lifetime, a gas-fired furnace has an operational life of 18 years, and a gas-fired water heater has an operational life of 14 years.

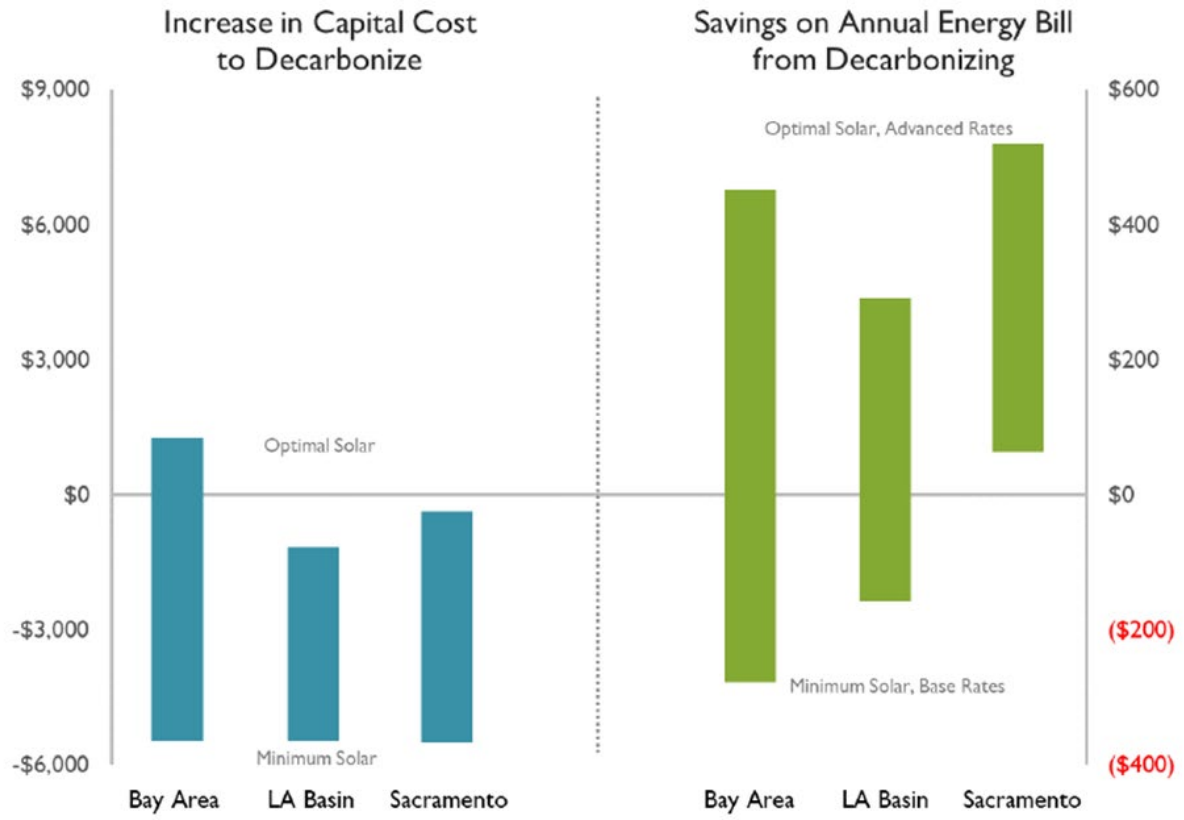


Figure 10: Capital costs of building new all-electric construction is equivalent in the Bay Area, LA Basin, and Sacramento, but annual energy bills can vary widely depending on location, largely due to different levels of air conditioning use. (Synapse, 2018)

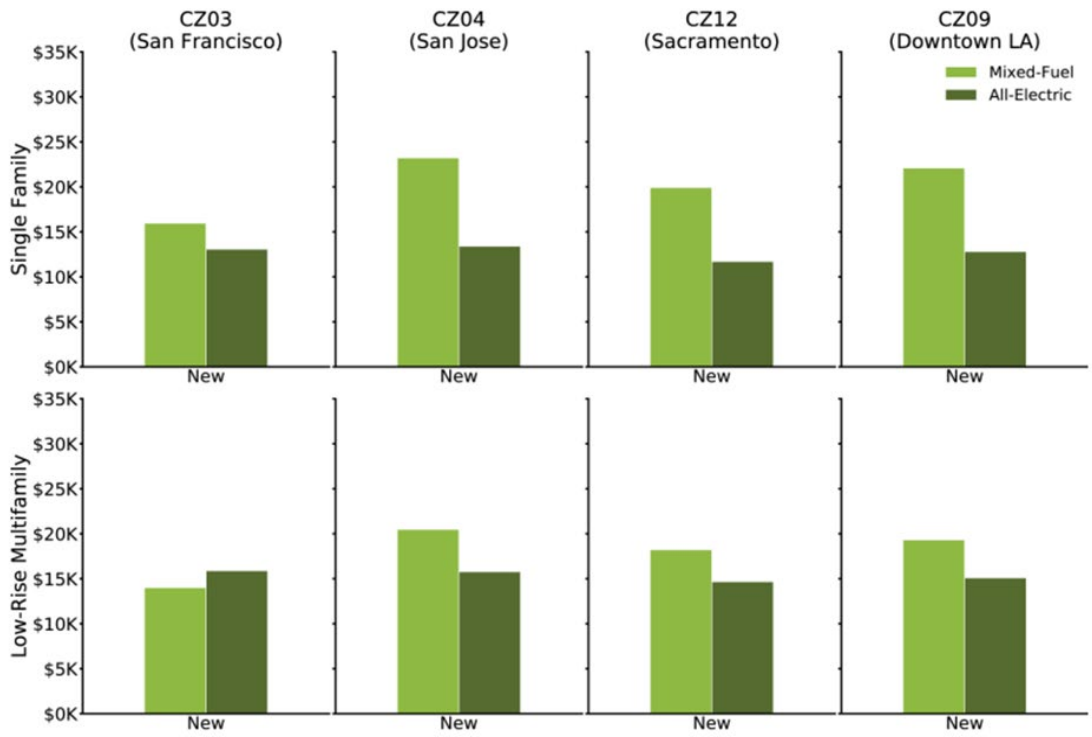


Figure 11: The capital costs required to build new all-electric buildings are lower than the capital costs for new mixed fuel buildings using both electric and natural gas-based heating in nearly all regions of California and for nearly all building types. (Synapse, 2018)

Potentially even more costly, dozens of gigawatts of renewable energy generation will need to be developed and interconnected to the electric grid if building and transportation electrification and renewable electricity generation continue to grow to meet the state's decarbonization goals. The Synapse report found that in a scenario where half of the state's methane use is substituted with electricity, electrical load served by the California Independent System Operator would jump from about 32 gigawatts to about 40 gigawatts during the daily winter peak load time of 6 p.m. (Synapse, 2018) That 25 percent growth in load will require not just new renewable generation but also new transmission lines, which would mean overcoming significant regulatory, planning and environmental challenges to build out. The CAISO estimates that meeting the state's decarbonization goals will require adding 85 gigawatts of generation capacity by 2035 and $6.1 billion in new transmission infrastructure. (California ISO, 2024) Planning, studying, approval, and construction of each transmission project can take eight to 10 years, according to CAISO - a timeline that points to the urgency of planning now for the projected increase in California's electrical load that will be required to meet the state's electrification goals. (California ISO, 2024)

Taken as a whole, meeting California's building electrification and decarbonization goals will require substantial investments from both the public and private sectors. One question that this research raises is whether public subsidies for private sector decarbonization will be needed to complete this transition and if so, how sizable those subsidies should be. If up-front capital as well as building retrofit costs end up presenting a major financial obstacle, with only moderate ongoing savings from reduced energy use, how much are governments and utilities willing to spend to help restaurant owners bridge that financial gap?

This work tackles this economic question from the perspective of one popular Sacramento restaurant interested in electrifying its kitchen. The co-owner of the restaurant wanted to know how much it would cost his restaurant to buy all-electric kitchen equipment, upgrade his electrical system, and operate his new electric kitchen from month to month. No published previous research has tracked the performance of induction stovetops in commercial kitchen settings or tracked their impact on energy use and cost in restaurants. With that information gap in mind, this chapter offers an in-depth case study that estimates up-front capital and ongoing operating costs for this Sacramento restaurant. This research also uses publicly available end-use energy data compiled by the California Energy Commission to estimate gas- and electric-powered kitchen energy costs for restaurants operating in different utility service territories.

At heart, this research provides valuable context for the current restaurant electrification debate by suggesting what restaurants are really up against financially when they electrify their kitchens. This information could help inform policymakers exploring implementing up-front and possibly ongoing subsidies for commercial kitchen electrification efforts. This research also adds a needed reality check for electrification advocates and policymakers eager to promote commercial kitchen electrification. Restaurants cannot electrify if they can't pay for it, and the up-front capital costs of electrification must be offset somehow - through lower operating costs or public subsidies or some other strategy.

Research Project 3: Commercial Kitchen Electrification Cost and Energy Budget

Project Overview

This research worked with a popular Sacramento restaurant over a year to gauge the up-front and ongoing costs of transitioning to electric-powered cooking. Partnering with the Sacramento Municipal Utility District (SMUD), this research audited the restaurant's current electricity and natural gas use and estimated what the restaurant's energy costs would be if it only used electricity

in its kitchen. This research also estimated the cost of purchasing electric kitchen equipment that could fulfill the functions of the restaurant's current gas-powered equipment. Finally, this research queried the restaurant's co-owner and staff to learn how their restaurant operated using natural gas-powered equipment, and to understand their hopes and concerns about switching to electricity-powered cooking equipment.

Objectives

This research aims to:

- Track the energy use and costs of commercial kitchen electrification.
- Track greenhouse gas emissions produced by using electric induction equipment compared to using natural gas-burning cooking equipment.
- Gain insight into the concerns of one restaurant when weighing whether to switch to induction stoves and other forms of electricity-powered cooking.

Referring to the California Restaurant Association lawsuit against the City of Berkeley, this research addresses the association's contention that "a shift to 'all electric' also will impose greater costs on Berkeley businesses and consumers, in the midst of an affordable housing crisis." (California Restaurant Association, 2019)

Methods

This research examined the restaurant's current practices and energy use patterns and conducted an energy audit to estimate its current monthly gas and estimated electricity costs based on its current business volume. For the energy audit portion of this research, this research worked with SMUD and the energy efficiency services company Frontier Energy to examine the restaurant's kitchen, electrical and ventilation systems to identify potential areas of increased energy efficiency and insulation improvement. The audit also inventoried the type of kitchen equipment being used by the restaurant for different types of cooking over the restaurant's operational timeline. The audit then paired those cooking functions with electricity-powered equivalents to determine comparable energy use and greenhouse gas emissions.

Separately, this research calculated the capital costs solely of purchasing the specified electricity-powered equipment to better understand the time required for estimated monthly energy cost savings to offset up-front capital costs. This audit took into account potential utility-offered subsidies for purchasing the electricity-powered equipment when calculating up-front capital expenditures. This audit did not estimate other costs such as any electrical upgrades needed to handle the increased load of an electric-only kitchen, any training needed for kitchen staff to learn how to cook on electricity-

powered equipment, time the restaurant would need to shut down to complete any kitchen upgrades, as well as the purchase of new steel pots, pans, and other kitchen equipment needed to conduct heat from electric induction stoves.

Contributions to Literature

This research contributes a quantitative analysis of energy costs and greenhouse gas emissions before and after commercial kitchen electrification for a specific restaurant. Current electrification literature looks largely at the energy costs of residential electrification but does not do the math for restaurants seeking to electrify. Importantly, this analysis looks at both up-front capital costs as well as ongoing monthly energy spending and addresses whether those up-front costs can be reasonably offset by monthly energy savings. Seen as a whole, this research provides a viability analysis to determine whether restaurants can realistically afford the up-front and ongoing costs involved in electrifying their kitchens.

This data also builds on California Commercial End Use Surveys (CEUS) conducted by the California Energy Commission examining energy use by different commercial building types. The latest CEUS conducted in 2022 found that natural gas use still dominated the state's restaurant commercial cooking space, with 71.5 percent of such spaces powered by gas and 27 percent of commercial cooking spaces powered by electricity. (California Energy Commission, 2023) Natural gas use dominated commercial kitchen spaces in California despite past CEUS results showing that restaurant electric cooking was more than four times more efficient than restaurant gas cooking use per square foot in Pacific Gas and Electric Company's service territory. (California Energy Commission, 2002-2006) The differential in energy use efficiency per square foot of restaurant space was about the same for gas and electric kitchens in the service territories of Southern California Edison, San Diego Gas & Power Co., and the Sacramento Municipal Utility District, according to the 2002-2006 California Energy Commission CEUS numbers.

The energy audit conducted for this work echoes those California Energy Commission efficiency findings by calculating substantial energy cost savings for an all-electric kitchen compared to a natural gas-powered kitchen at the same Sacramento restaurant despite electricity still costing substantially more than natural gas per unit of energy in California. That is likely a result of greater efficiencies when comparing electricity and natural gas use, with an electric kitchen in the Sacramento restaurant projected to use 26.2 percent of the equivalent energy units as the restaurant currently uses in its gas-powered kitchen to perform the same functions. As electricity grows cheaper to generate with the addition of more renewables to the state's grid, that cost differential

should continue to widen between electricity and natural gas consumption for the same end uses.

Results

The energy audit described here sought to replicate as closely as possible the cooking capacity and variety of the Sacramento restaurant's current gas-powered kitchen. To do that, the energy audit inventoried the following existing natural gas-powered equipment in the restaurant's kitchen:

- 1 convection oven, built underneath the range and used largely to bake fish, poultry, and other meats
- 10 open burners on a gas-powered range, used for sauteing, frying, and other cooking done in pans and pots
- 2 range ovens, largely used for roasting and broiling
- 1 24-inch griddle, used for cooking eggs, potatoes, and other foods in larger batches
- 2 fryers, used for French fries and other fried foods

The audit calculated the kitchen equipment's energy use and carbon intensity as follows:

- 1 convection oven uses 525 therms per year with a carbon intensity of 2.8 metric tons of carbon dioxide.
- 10 open burners use 1,700 therms per year with a carbon intensity of 9 metric tons of carbon dioxide.
- 2 range ovens use 1,000 therms per year with carbon intensity of 5.3 metric tons of carbon dioxide.
- 1 24-inch griddle uses 580 therms per year with a carbon intensity of 3.1 metric tons of carbon dioxide.
- 2 fryers use 1,559 therms per year with a carbon intensity of 8.3 metric tons of carbon dioxide.

In total, the restaurant's kitchen uses an estimated total of 5.364 therms per year with an annual carbon output of 28.4 metric tons of carbon dioxide.

The audit calculated the energy cost of each existing category of kitchen equipment as follows:

- 1 convection oven costs $1,050 in energy consumption per year.
- 10 gas burners cost $3,000 in energy consumption per year.
- 2 range ovens cost $2,000 in energy consumption per year.
- 1 24-inch griddle costs $1,160 in energy consumption per year.
- 2 fryers cost $3,118 in energy consumption per year.

In total, the restaurant's kitchen costs an estimated $10,328 in natural gas consumption per year. As a point of reference, the restaurant's PG&E bill

showed it spending from $519.63 in July 2022 to $644 in October 2022 for monthly natural gas consumption.

The audit estimated replacing the natural gas-powered equipment with the following equipment:

- 2 electricity-powered Rational brand convection ovens, used as direct replacements for the gas-powered convection ovens
- 1 6-pan half-size Rational brand combi oven, capable of cooking eggs, roasting vegetables, and performing other cooking tasks in different pans at the same time
- 12 electric induction hobs, direct replacement for the 12 gas-powered burners currently being used
- 2 electricity-powered fryers, direct replacement for the restaurant's two natural gas-powered fryers currently being used

Notably, the audit estimated replacing the gas-powered range ovens with the electric half-size combi oven. The audit also replaced the 24-inch gas-powered griddle with two additional induction hobs.

The audit estimated the energy use and carbon intensity of the electric equipment as follows:

- 2 convections ovens were estimated to use 10,700 kWh of electricity per year with a carbon intensity of 2.2 metric tons of carbon dioxide.
- 1 6-pan half-size combi oven was estimated to use 3,450 kWh of electricity per year with a carbon intensity of 0.7 metric ton of carbon dioxide.
- 12 induction hobs were estimated to use 15,000 kWh of electricity per year with a carbon intensity of 3 metric tons of carbon dioxide.
- 2 fryers were estimated to use 12,036 kWh of electricity per year with a carbon intensity of 2.4 metric tons of carbon dioxide.

In total, the all-electric equipment was estimated to use 41,186 kWh per year with an annual carbon output of 8.3 metric tons of carbon dioxide. Based on these results, the electricity-powered kitchen produced 20 metric tons of carbon dioxide less than the restaurant's current natural gas-powered kitchen.

The audit estimated the electric kitchen equipment's energy costs as follows:

- 2 convection ovens cost $1,926 per year in energy consumption.
- 1 6-pan half-size combi costs $621 per year in energy consumption.
- 12 induction hobs cost $2,700 per year in energy consumption.
- 2 fryers cost $2,166 per year in energy consumption.

In total, the all-electric equipment was estimated to cost $7,413 per year in annual energy costs. As a point of reference, the restaurant's SMUD bill, which covered all electricity use, showed the restaurant's average monthly electricity

consumption at 5,680.25 kWh from November 2021 to October 2022 with an average monthly invoice of $872.81.

Based on these results, the electricity-powered kitchen equipment cost $2,915 less in annual energy consumption than the restaurant's current natural gas-powered kitchen equipment. The bulk of these energy savings result from not replacing the 24-inch gas-powered griddle, which is estimated to consume $1,160 a year in gas. The cost of powering the electric convection and 6-pan half size combi ovens partially offset the savings earned from not replacing the gas-powered griddle, with the electric ovens costing 83 percent more to power per year than the gas-powered convection and range ovens they replace. The overall result matched the findings of a Frontier Energy case study of a single piece of French Top cooking equipment calculating an annual operating cost of $2,340 for the gas-powered French top compared to $1,650 for the induction range top, or a 29 percent energy cost savings with the electric replacement. (Frontier, n.d.)

The full energy audit cost results are showing here in Table 6. The full energy audit greenhouse gas emissions results are shown in Table 7.

Table 6: Cost results of energy audit conducted at a Sacramento restaurant comparing energy costs using natural gas-powered equipment and alternate electric-powered equipment.

Existing Natural Gas Equipment				Alternate Electric Equipment			
Category	**Qty**	**Energy Use (Therms/yr)**	**Energy Cost ($)**	**Category**	**Qty**	**Energy Use (kWh/yr)**	**Energy Cost ($)**
Convection Oven	1	525	1,050	Convection Oven	2	10,700	1,926
				6 Pan Half Size Combi	1	3,450	621
Open Burners	10	1,500	3,000	Induction Hobs	12	15,000	2,700
Range Ovens	2	1,000	2,000				
24" Griddle	1	580	1,160				
Fryers	2	1,559	3,118	Fryers	2	12,036	2,166
Totals		**5,164**	**10,328**			**41,186**	**7,413**
Electric Difference							**-2,915**

Table 7: Greenhouse gas emission results of energy audit conducted at a Sacramento restaurant comparing emissions using natural gas-powered equipment and alternate electricity-powered equipment.

Existing Natural Gas Equipment				Alternate Electric Equipment			
Category	**Qty**	**Energy Use (Therms/yr)**	**Carbon Intensity (mt/CO2)**	**Category**	**Qty**	**Energy Use (kWh/yr)**	**Carbon Intensity (mt/CO2)***
Convection Oven	1	525	2.8	Convection Oven	2	10,700	2.2
				6 Pan Half Size Combi	1	3,450	0.7
Open Burners	10	1,700	9.0	Induction Hobs	12	15,000	3.0
Range Ovens	2	1,000	5.3				
24" Griddle	1	580	3.1				
Fryers	2	1,559	8.3	Fryers	2	12,036	2.4
Totals		**5,364**	**28.4**			**41,186**	**8.3**
Electric Difference							**-20**

*Based on SMUD's *General Mix* having a 2022 reported Greenhouse Gas Emissions Intensity of 0.446 lb CO_2/MWh. Note that SMUD's Alternative Power Generation Plans have a 2022 reported Greenhouse Gas Emissions Intensity of 0.0 lb CO_2/MWh resulting in 0.0 mt/CO_2/yr carbon emissions for the electric cooking equipment.

While those savings are sizable, the capital costs needed for any commercial kitchen electrification project are substantial. Based on costs listed in commercial kitchen equipment retail websites, the retail costs for the electric-induction equipment used in this audit came out as follows:

- $49,920 for three Cooktek MC-17004-200 countertop 4-burner induction ranges at $16,640 per range (Katom, n.d.)
- $15,140 for one Zephaire full-size standard depth convection ovens (Webstaurant, n.d.)
- $28,272 for one Rational brand ICP 6-pan half-size combi oven (Katom, n.d.)
- $14,686 for two Frymaster RE14 electric fryers at $7,343 per fryer (Katom, n.d.)

In total, the electric equipment estimated to replace natural gas-powered equipment in the Sacramento restaurant's kitchen would cost $108,018 in capital costs.

As part of this energy audit, SMUD estimated the following rebates available for the electric equipment under consideration for the Sacramento restaurant:

- $750 rebate for the electric convection oven
- $1,500 rebate for the 6-pan half-size combi oven
- $12,600 in total for the three 4-hob induction ranges
- $750 in total for two electric fryers.

After subtracting these rebates from the up-front capital cost of the electric induction equipment considered for this electrification project, the total capital costs of purchasing the electric kitchen equipment came out to $92,418.

Discussion

These results clarify the financial challenges that restaurants face in electrifying their kitchens. Simply put, the up-front capital costs of making the switch outweigh the savings achieved in restaurants' energy bills. In fact, based on this research, it appears that restaurants' energy costs are simply not substantial enough to play any major role in decisions about whether or not to electrify. Even if this Sacramento restaurant saw its monthly energy bill drop to zero, it would still take 10.5 years for it to recoup its up-front capital costs just to purchase the recommended electric kitchen equipment without any SMUD rebates. After factoring in SMUD rebates, the audit finds that it would take the restaurant nine years to recoup those equipment capital costs based on the estimated energy bills of natural gas-based cooking equipment and SMUD rebates for electric cooking equipment. As the restaurant co-owner said while reviewing the energy audit's results, saving $242 a month in energy costs just isn't large enough of an incentive to justify the cost, time, and uncertainty of switching from gas-powered to electric cooking. As noted previously, this calculation doesn't include other substantive electrification costs such as any needed electrical upgrades, staff retraining, restaurant shutdown during renovations, and new steel cooking equipment capable of heating up on an induction stove.

Perhaps the biggest obstacle for this restaurant's co-owner was simply fear of the unknown. The co-owner noted that the restaurant business has been notoriously risky in recent years, which makes betting on an expensive new technology a hard sell. The co-owner only agreed to explore kitchen electrification because he was interested in the environmental benefits of induction cooking. He also believed that the restaurant being publicly known for

its environmentally friendly practices would be a selling point for customers. In the end, however, the restaurant co-owner simply didn't have the up-front cash to make electrification work and didn't want to put his business at risk. Those comments echoed the sentiments of three other restaurant owners interviewed for this research. To a person, all of the restaurant owners emphasized the tight profit margins they were operating under and their reluctance and inability to take the risk to convert to a new technology that might undermine their bottom line.

Focusing just on the cost analysis, this research raises questions about the kinds of public subsidies that would be needed to help restaurants interested in electrification overcome up-front financial hurdles. As noted previously, most California utilities already offer rebates on electric kitchen equipment, but those subsidies only cover a tenth or so of the total cost. Even if governments had the budget and desire to cover the rest of the capital costs, it seems unlikely that any public entity would be willing to subsidize all restaurant electrification costs if the total amount is anywhere near what's estimated in this research. Again, this research doesn't analyze pro-electrification subsidies and policy tools, but it hopefully offers some idea about the practical challenges involved in convincing restaurants to make the switch. To restate the underlying theme of this work, restaurants face real financial, as well as cultural and thermodynamic, hurdles in electrifying their kitchens, and policy-makers and advocates should take into account such obstacles when mandating restaurant electrification.

One other potential strategy for increasing the viability of commercial kitchen electrification is to quickly bring down the cost of the equipment itself. Commercial scale electric cooking equipment is still early in its adoption curve, which means that similar to the history of other technologies, volume is low and costs are still high. If adoption of electric induction cooking equipment accelerates, and especially if a food service company with multiple locations decides to switch to induction cooking, that would surely increase the volume in induction equipment sales and drive down costs. As Cowan describes in *More Work for Mother*, wholesale adoption of new domestic technologies has historically occurred in tandem with falling costs, and in the process transformed the social dynamics around the impacted type of work. (Cowan, 1983) If all that does come to pass with electric induction cooking, at least the economic obstacles of kitchen electrification will be lowered. That, in turn, may lower the risk and therefore the psychological barriers for restaurants seeking to electrify their kitchens.

Finally, previous research has shown that opening a new all-electric restaurant is less expensive than transitioning an existing gas-powered kitchen to all electricity or even opening a new gas-powered restaurant. (Synapse, 2018) When considering subsidies or other incentives for electrifying restaurant kitchens, focusing on new all-electric kitchens may be the best way to target

support that can really make a difference. If a couple thousands of dollars would make a real difference for helping a restaurant trying to open a new electric kitchen, public incentives of that scale could make a difference in whether that restaurant opens or not, as opposed to the tens of thousands of dollars needed to help electrify an existing natural gas-powered restaurant kitchen given current capital costs. New all-electric restaurants might present the sweet spot in terms of needed support and available public dollars for providing that support.

Limitations to Research

This research provides a case study of one Sacramento restaurant comparing its current natural gas use to a hypothetical all-electric kitchen scenario. Within that scope, this audit produced enough information for the restaurant co-owner to decide he could not afford electrification at this time and that he should continue operating his restaurant with natural gas-powered equipment. To understand the per-restaurant costs of commercial kitchen electrification throughout California, however, energy audit data from more restaurants would clearly have helped capture a wider range of kitchen electrification impacts accounting for varieties in restaurant size and layout, utility rates, and types of cuisine cooked. That said, conducting multiple energy audits for this work ultimately proved prohibitively time intensive. As one example, in just the case of the Sacramento restaurant that did participate in this study, the front-to-end process of introductory meetings, kitchen visits, and other conversations seeking to convince the restaurant co-owner just to participate in the energy audit took about a year, with several false starts and multiple extended periods of silence from the restaurant. Restaurants are famously high-pressure workplaces, and the vast majority of them just don't have the time to talk about a hypothetical situation such as kitchen electrification. In this case, a personal introduction to the restaurant co-owner ultimately helped win his trust from the outset, which helped overcome the initial reluctance expressed by about a dozen other restaurants approached to participate in this study.

Acknowledging these limitations, the results produced by this case study may still be applicable to other restaurants due to the dramatic gap between the energy savings estimated with electrification and the upfront capital costs required to renovate the restaurant's kitchen. The reality that this audit underlines is that high-end commercial electricity-powered kitchen equipment still costs multiples of the price of natural-gas powered kitchen equipment, and it is simply fantasy to expect that energy savings will quickly help restaurants recoup these up-front costs. As one example, one six-burner commercial gas range with two built-in convection ovens cost $3,152 a piece (Katom, n.d.), compared to $16,640 for a four-hob electric induction stovetop (Katom

Restaurant Supply, n.d.) and $28,272 for a Rational brand 6-pan half-size electric combi oven. (Katom Restaurant Supply, n.d.) For the Sacramento restaurant in this study, its total yearly natural gas bill was estimated to be $10,328. As stated earlier, even if this cost were to entirely go away, it would still take about nine years to recoup the up-front costs of just purchasing the electricity-powered kitchen equipment.

In practice, the payback time for kitchen electrification would likely be even longer since this study did not estimate other up-front costs such as electrical system renovations and staff retraining. On the other hand, this audit also did not consider potential ongoing savings from electric induction cooking such as reduced air-conditioning needs due to the much lower amount of waste heat produced by electric induction stoves compared to gas ranges as well as lower health care costs for kitchen employees due to the lower amount of carbon monoxide, nitrogen dioxide, and particulate matter produced by electric induction stoves compared to gas-powered stoves. (Zhu, 2020) These potential additional costs and savings can be highly variable depending on the layout of the restaurant kitchen, the foods cooked there, kitchen practices, and numerous other factors.

One last detail of note is that this research had aimed to model the energy costs of different types of gas-to-electric kitchen transitions based on disaggregated California Commercial End-Use Survey data. That data ultimately proved inaccessible due to non-disclosure agreements signed by both state survey administrators and surveyed businesses. The California Energy Commission was only able to offer summary CEUS data. If future researchers can find a way to access that dataset, that data could inform a cost model estimating a range of kitchen electrification energy costs and savings based on the specific traits of each restaurant without having to perform individual energy audits.

Chapter 4: Thermodynamic Food Transformations with Gas and Electric Stoves

Technical Background

Directly cooking meats and vegetables over flame can produce distinctive tastes and textures that are widely considered part of the essential experience of those dishes. With meat in particular, grilling or broiling can quickly brown its surface and trap the meat's juices within. (McGee, 1984) Cooking over flame also produces a smokey flavor to meats and vegetables that electric induction stovetops just can't replicate, at least with current technology. Beyond the direct application of flame to foods, however, cooking in a pot, pan, or wok over flame can also catalyze unique thermodynamic transformations within the pan that produce certain desired tastes and textures that electric induction stoves may not be able to replicate. Multiple survey responses detailed in Chapter 1 cited just such flame-fueled heating results such as for carne asada and stir-fries. In particular, several Mandarin-speaking respondents named Sichuan beef, which is known for its crispy, flavorful texture when flash fried in a wok. The co-owner of Noodles Fresh in Berkeley echoed those comments by pointing to what she called induction stoves' inability to replicate the intense heat spikes produced by flame cooking in a wok that are important tools of the trade in Chinese restaurants. As stated earlier, the California Restaurant Association has specifically cited wok cooking in its lawsuit against the City of Berkeley as a practice that induction cooking cannot replicate and a reason why natural gas bans hurt the state's ethnic restaurants.



Figure 12: Cooking chicken and vegetables to produce Jiangxi Noodle Sald over intense flame in a wok at the restaurant Noodles Fresh on March 7, 2025. The spike in heat produced by flame in the wok produces what is often called 'wok hei,' or a smoky searing of meat and vegetables that produces a crispy exterior to the food while retaining a savory, juicy interior.

What actually is happening in the pan or wok has become the subject of a growing genre of food writing detailing the science of heat transfer, molecular breakdown of meat fibers, caramelization, and other physical changes in ingredients during food preparation. McGee's seminal book *On Food and Cooking* takes a scientific approach to examining such cooking processes, including what he calls the "browning-reaction aromas" achieved when grilling or broiling with flame that "can produce the most flavorful results." (McGee, 1984) Food writer J. Kenji López-Alt extends that science-based approach to wok cooking in his 2022 book *The Wok: Recipes and Techniques*. López-Alt credits the special smokey flavor of wok-based stir-fry, what is often called *wok hei*, to the specific movements used in wok cooking: tilting the wok slightly away from the cook, pushing the wok forward in a smooth, gentle motion, and then pulling the wok back toward the cook with a quick jerk that sends the food flying into the air, and finally catching the food in the work as the cook tilts the wok. (López-Alt, 2022) López-Alt also references the intentionally uneven temperatures in a wok, with the bottom of the wok quickly heating up to over 550 degrees Fahrenheit while the sides of the wok stay cool.

López-Alt writes:

With wok cooking, you want different temperature zones inside the pan. You want a screaming-hot part at the very bottom. You want slightly

cooler regions around the edges. You want heat rising up the sides of the wok and curling over the edge so that when you fling food up in the traditional stir-fry method, it hits a column of hot, steamy air. When food is pushed up to the sides, the bottom very rapidly comes back up to hard-searing temperatures, priming it for the next ingredients. (López-Alt, 2022)

López-Alt then specifically addresses the capacity of electric burners and induction burners to reproduce *wok hei* in stir-fries. His verdict: It's possible but "more difficult than with a gas burner."

First, the need to toss stir-fry ingredients presents challenges for induction woks because doing that will likely require lifting the induction wok from its base. As a result, the wok will not stay in constant contact with the base, which will interrupt the heat flow to the pan since induction stoves require contact with the pan to generate heat. As López-Alt describes, the wok actually needs a spike of intense heat when it is being tossed as opposed to a loss of heat.

Also, López-Alt adds:

…[E]lectric burners are not as responsive as gas burners. When stir-frying, you'll find that you frequently switch between high heat and low heat or even no heat. This is easy on a gas burner: more or less gas = instantly higher or lower heat. An electric burner, on the other hand, takes a long time to heat up and cool down (induction burners are more responsive than electric burners, but not as responsive as gas)…

Second, and most important: electric and induction burners heat only the part of the pan in direct contact with the burner. This means that with a flat-bottomed wok, only the flat part of the wok will get heated. While it's true that in a stir-fry you want heat to be concentrated on this area, a gas flame will still spread some of its energy to the sides of the wok. This is particularly important for achieving wok hei, as that heat around the edges is (a) what allows you to sear sauces when adding them around the lip of the wok and (b) creates the column of hot air and steam along the back of the wok that promotes rapid cooking and singeing of fats. (López-Alt, 2022)

What exactly is *wok hei* is sometimes debated, with some challenging its very existence. Steph Li, host of the YouTube channel Chinese Cooking Demystified, described it as: "Wok hei is this ethereal thing … that taste of the first bite of a hot restaurant stir-fry. It's got that taste of the restaurant oil, the slightly deeper restaurant browning, the heavier restaurant seasoning." (López-Alt, 2020)

Finally, several studies conducted by Chinese researchers looked at the physical cooking properties that produce desired flavors and textures in Chinese dishes such as *wok hei*. One study investigated the effects of different cooking

methods (frying, steaming, and boiling) on volatile flavor compounds in beef using solid phase microextraction (SPME) combined with gas chromatography-mass spectrometry (GC-MS). (Liu, 2022) The study found that frying had the strongest impact on volatile compounds likely due to the higher temperatures achieved with that method, followed by steaming, while boiling had the least effect. The article showed the chemical compounds of frying with high peak temperature promotes faster oxidation of fats and degradation of esters and acids, leading to browning compounds like pyrazines and aldehydes and smoky flavor. As a result, the study concludes that flame can best create that high peak effect in beef.

Another Chinese study provided evidence that induction stovetops can adequately cook at least some stir-fried dishes such as braised pork. (Da, 2021). The study compared concave electromagnetic induction heating (2000 W) with traditional flat electromagnetic heating for their effects on braised pork's texture, flavor, and nutritional content. The study found that concave electromagnetic induction heating reduces cooking time while maintaining quality and that texture metrics such as hardness, chewiness, and cohesiveness decreased over time, while volatile flavor compounds and fatty acid content varied. The study found that concave electromagnetic induction heating can improve the texture, flavor, and efficiency of braised pork preparation compared to flat electromagnetic induction heating elements.

This chapter builds on that work by detailing how different electricity- and natural gas-powered heating techniques actually cook certain foods and whether that type of cooking produces dishes that fit people's mental models of those foods. To describe that cooking process, the academic and popular literature around the science of cooking as well as the guidance of UC Berkeley Mechanical Engineering Professor Lydia Sohn have helped this work incorporate into its discussion thermodynamic concepts such as conduction, convection, and other heat-transfer processes and the amount of heat and time needed to produce specific results such as caramelization and Maillard reactions. This research field also examines the thermodynamic principles of flame-grilling, braising, boiling and other types of cooking methods, and how such cooking practices physically transform the cellular make-up of meats, vegetables and other ingredients. This research seeks to identify what electric cooking can and can't physically accomplish in commercial kitchens, particularly in relation to wok stir-frying – and whether any substitutes exist for the types of flame cooking that electric stovetops can't replicate.

This chapter focuses on wok cooking in particular as a response to the California Restaurant Association's and other natural gas cooking advocates' arguments that electric induction stovetops cannot duplicate the effects of wok cooking on high flame - arguments supported by López-Alt. Through these kitchen experiments, this chapter will test the findings of López-Alt and

determine any thermodynamic limitations to induction stovetop, and induction wok cooking in particular.

Research Project 4: Cooking Diverse Dishes on Flame and Electric Induction Stoves

Project Overview

The research described in this chapter uses an induction stovetop, an induction wok, and two types of electric combi ovens to prepare a variety of foods such as quesadillas, poached eggs, bacon, Chinese pepper steak, stir-fried Udon noodles, and beef stir-fried with green onions. This research aims to produce different textures and flavors on induction equipment such as crispy braised beef and the browned tortillas of a quesadilla. This chapter also aims to test the findings of López-Alt about the limitations of induction woks in stir-frying as well as gauge the general capabilities of induction stovetops and woks to produce the same results as their gas-powered counterparts for different dishes.

Objectives

This research aims to duplicate on an induction burner and in an electric combi oven the flavors and textures desired in dishes cooked on flame, focusing on commonly cited dishes that might be hard to replicate on electric induction cooktops. In particular, this research explores the capacity of induction cooking technology to reproduce the unique *wok hei* flavors popular in Asian stir-fry dishes.

Relation this research to the California Restaurant Association's lawsuit against the City of Berkeley, this research addresses the association's contention that "[m]any of these restaurants rely on gas for cooking particular types of food, whether it be flame-seared meats, charred vegetables, or the use of intense heat from a flame under a wok. Indeed, restaurants specializing in international foods so prized in the Bay Area will be unable to prepare many of their specialties without natural gas." (California Restaurant Association, 2019) This research tests this contention by attempting to duplicate dishes mentioned in the complaint on electric induction equipment.

Methods

This research tested various types of electricity-powered cooking equipment over three months to prepare dozens of dishes from a diverse range of cuisines. The cooking experiments tested the ability of electric equipment to perform thermodynamic processes such as quickly browning beef, vaporizing liquids in a wok, baking meats and eggs, and browning tortillas. The results of these experiments were judged by methods such as blind taste tests and the

physical inspection of the amount of liquid and browning qualities observed in the resulting dishes.

At the start of this research, the co-owner and one kitchen staff member of the Sacramento restaurant featured in Chapter 3 visited a test kitchen, also in Sacramento, on August 21, 2023 to try out various pieces of cooking equipment, most of them electric. The demonstration was funded by the Sacramento Municipal Utility District's commercial kitchen electrification program and was led by a chef from a Reno-based country club kitchen. The equipment tested were:

- A natural gas- and electric-powered Rational iCombi Pro 6-full size oven able to cook six different dishes simultaneously when placed on different racks. The oven can produce 60-160 meals per day, per Rational's technical specifications.
- An electric-powered Rational iCombi Pro XS oven able to cook three different dishes simultaneously when placed on different racks. The oven can produce 20-80 meals per day, per Rational's technical specifications.
- A portable electric induction burner with steel pan.

The restaurant co-owner watched the test kitchen chef prepare egg and bacon sandwiches on English muffins as well as roasted meats in the Rational iCombi Pro 6-full size oven and the electric-powered Rational iCombi Pro XS oven. The restaurant co-owner also used the portable induction burner to cook his own egg dishes after first testing the heat produced by the induction burner by dropping a bit of water on the pan to see how it cooked. After testing or watching several electric-powered appliances prepare different dishes, the restaurant co-owner said he was impressed with the results although he also said he wanted to spend more time cooking on a commercial-grade electric induction stove.

As a subsequent part of this research, a 1500-watt Nuwave Mosaic Precision Induction Wok and an 1800-watt Duxtop Portable Induction Countertop Burner Induction Hot Plate were tested from August to November 2024 to cook everyday meals in the author's house as well as to prepare in his aunt's house and in a UC Berkeley student kitchen specific Asian stir-fry dishes that required thermodynamic processes unique to wok cooking. The Duxtop induction burner has a maximum temperature of 460 degrees Fahrenheit, while the Nuwave wok has a maximum temperature of 575 degrees Fahrenheit. The Nuwave's maximum temperature appeared to at least match that of far more expensive commercial models of induction woks such as the Spring USA SM-351WCR-6 MAX Induction wok priced at $2,766.65 each and with a maximum temperature of 400 degrees Fahrenheit. (Webstaurant Store, n.d.) Similarly, the Spring MAX Induction 1800W Cook and Hold Induction Range, priced at $694 each, is listed with a maximum temperature of 400 degrees Fahrenheit, below

the maximum temperature listed for the Nuwave Mosaic induction stovetop. (Spring USA, n.d.)

The Nuwave was used over three months on a daily basis to cook all three meals of the day. The Duxtop was used in five wok cooking experiments in August and October 2024 to flash fry meats and vegetables. The Nuwave wok was used to cook Chinese beef stew, pork and green beans, beef with green onions, and pepper fried steak. Again, the results of the process were evaluated through several taste tests among colleagues and family members.

Contributions to Literature

This research contributes to the existing electrification literature by providing an up-close look at whether electric induction cooking can replicate the flavor of dishes traditionally cooked on flame. Again, the current electrification literature largely does not address the differences in flavor, texture, and other culinary attributes of food produced with electric induction equipment when compared to dishes cooked with flame. The current trend in food science literature, including works such as Cook's Illustrated's *The Science of Good Cooking* and Harold McGee's *On Food and Cooking: the Science and Lore of the Kitchen,* also largely do not distinguish between cooking with flame and electric induction stoves. This research recognizes the differences between the two cooking methods and illuminates how such different methods translate into possible differences in the completed dishes. This research also adds data to the findings reported in López-Alt's book on wok cooking by further testing whether induction woks can replicate the textures and smoky flavors typical of stir-fries cooked with flame.

Overall, this research adds data to the debate between pro-gas and pro-induction advocates about the capabilities of induction cooking equipment especially in flashy-frying Asian stir-fries. López-Alt himself writes in *The Wok: Recipes and Techniques* that the question he is asked most frequently is whether electric or induction woks can faithfully produce tasty stir-fries with the same flavor produced over flame. Of course, kitchen experiments only generate a few data points, but these results can hopefully help to inform this ongoing debate.

Results

The results of multiple cooking experiments as well as insights gleaned from the daily use of induction cooktops largely confirmed what previous literature has shown, with some exceptions. Induction stovetops do a great job cooking foods that require steady heat and not a lot of pan movement to achieve their desired flavors and textures. Induction stovetops are excellent at boiling water, frying eggs, melting cheese in a quesadilla, and heating pasta

sauce, among other uses. To cite one result, the co-owner and staff member of the Sacramento restaurant that visited the electric test kitchen said they were impressed with the taste and texture of the dishes produced with the electric combi oven and induction burner. The roast beef cooked in the Rational combi oven came out with a firm and well-cooked texture with a flavorful outer shell. The bacon also was baked to the right amount of crispiness, and the eggs were poached to a good consistency. That said, the restaurant co-owner said he would need to cook more technically challenging foods to come to a definitive conclusion about the capabilities of the combi ovens and induction burner. He also said he was interested in cooking on a commercial-level induction burner rather than the mobile burner available at the test kitchen to determine the technology's full potential.

That overall positive finding was echoed in the other kitchen experiments conducted as part of this chapter. Over six months of daily use, the Duxtop induction stovetop all but replaced the author's home kitchen gas burners in preparing every meal, with no noticeable difference in flavor or texture. It must be noted, however, that no grilling was needed during this time, so the induction stovetops' lack of flame did not prove to be an impediment to preparing meals. As discussed earlier, flameless induction stovetops by nature cannot brown meats or vegetables the way flame can to reproduce the cooked outer shell and smoky flavors of grilling and other flame-based cooking methods. Yet despite that gap in its repertoire, induction stovetops appear capable of serving the needs of many restaurant kitchens, especially those that don't require intense dynamics in cooking heat or flame grilling to finish off certain foods. Already, induction stove tops are hard at work in a few restaurants such as the popular macaroni and cheese joint Homeroom in Oakland and the West Sacramento cafe Franquette with its menu of French toast, quiche, and ratatouille - dishes that require steady, even heat but not flame-grilling or flash-frying.

Experiments using the Nuwave Mosaic induction wok to stir-fry foods produced mixed results. The Nuwave wok was twice unable to produce the desired crispiness when flash-frying beef, at least compared to the results of wok cooking beef over flame. For example, using the induction wok to prepare seared beef with green onions produced an overly chewy texture lacking the crunch essential to the dish's appeal, which wok frying over flame was able to produce. The flavors came out the same, but the textures were distinct enough to noticeably lower the quality of the induction-produced version of the dish, at least according to one taste tester. The Nuwave wok was set to its maximum temperature of 575 degrees Fahrenheit while cooking beef and green onions and ultimately took more than five minutes to complete the dish. That extended cooking time ended up drying out the beef a bit compared to the same set of ingredients cooked on flame. See Figure 13.



Figure 13: Flash-fried chuck beef with green onions prepared with the Nuwave induction wok (left) and a wok over flame (right).

Similarly, using the Nuwave induction wok to flash-fry Chinese pepper steak produced an overly chewy texture to the meat. The induction wok was also unable to produce the flashes of intense heat needed to quickly vaporize added water and quickly steam the steak as it fried in the wok. Instead, the beef and vegetables ended up boiling in the wok for several minutes, producing more of a stew than a stir-fry. By contrast, flame-heated woks are capable of quickly vaporizing water that is added during the wok's peak level of heat so that the meat is quickly steamed and browned. The Nuwave wok was set at its maximum temperature of 575 degrees Fahrenheit, with the lid sometimes covered to conserve heat. The wok was rolled back and forth within the rounded induction base unit, but it wasn't lifted at all due to the need for contact with the base unit to generate heat. As a result, the ingredients could not be tossed as López-Alt describes the process without creating drops in temperature just when a spike in heat was needed. Several people tested the resulting dish and confirmed the beef's chewy texture as opposed to the browned crunch of pepper steak stir-fried over flame. See Figure 14.



Figure 14: Chinese pepper steak cooked in the Nuwave induction wok. Note the unvaporized liquid in the wok that lengthened the dish's cooking time.

Of course, not all Chinese dishes require flash-frying or flash-steaming to taste the way they are supposed to. Plenty of Chinese dishes are boiled and steamed or require a simpler form of stir-frying that doesn't need spikes of intense heat and quick searing. To that end, the Nuwave wok was able to adequately cook less heat-intensive dishes such as Chinese beef stews and stir-fried green beans, with the wok not even needing to reach its maximum temperature of 575 degrees Fahrenheit to complete the dish. See Figures 15 and 16.



Figure 15: Green beans fried in the Nuwave induction wok.



Figure 16: Chinese beef stew cooked in the Nuwave induction wok.

As López-Alt writes in *The Wok: Recipes and Techniques*, flash-frying meats and vegetables in a wok produces unique heat effects that are necessary to completing certain dishes appropriately. The wok needs to generate a column of heat and steam that can rapidly cooks and singe fats. The wok also needs variable heat across its surface with the middle of the wok burning the hottest so that it can sear sauces on the cooler sides and flash fry in the intensely hot middle. Finally, the wok needs to be constantly tilted and jerked so that the ingredients inside are properly tossed, and it must be able to produce spikes of intense heat at critical junctures of the cooking process. (López-Alt, 2022) The Nuwave wok, like the Duxtop induction stove, was designed to produce even, steady heat to the pan. By design, it just couldn't provide the full palette of heating processes that some dishes required. It also couldn't be lifted from its base without losing heat, which prevented adequate tossing of the ingredients. This research confirmed López-Alt's conclusions about electric induction woks: They aren't ready yet for the full range of stir-frying techniques used by most Chinese restaurants.

Discussion

When applied to the commercial kitchen electrification context, this research points to the limitations of current technology to completely electrify the restaurant sector. As described earlier, grilling or broiling with direct flame is a process that induction equipment by nature cannot replicate, especially in producing the smoky flavor and charred texture that flame cooking is known for. This research suggests that even when direct flame isn't required, electric induction stovetops and woks still cannot adequately prepare certain dishes such as flash-fried meats and vegetables. The two Chinese restaurants interviewed for this research made that same argument about induction woks. The co-owner of Noodles Fresh said she liked cooking with induction stovetops and used one at home but had not yet found an induction wok that could adequately replace cooking in a wok over flame.

One possible work-around to induction cooktops' limitations that can still allow for scaling commercial kitchen electrification is operating dual-fuel kitchens that can run both on grid-provided electricity and a secondary heat source fueled outside of the utility electricity and gas system. This solution was acknowledged during the demonstration of electric equipment at the Sacramento test kitchen where the chef running the demonstration said he still used a wood-fired oven in the Reno-based private club where he worked to supplement the electric cooking equipment in his kitchen. López-Alt makes the same proposal by suggesting all-electric kitchens use portable gas burners that run on butane cartridges to power flame-heated woks. (López-Alt, 2022) That likely isn't a viable approach for Chinese restaurants such as Noodles Fresh that are highly dependent on wok cooking to produce nearly all of their dishes, but it

can be a strategy for restaurants where stir-fried dishes requiring the *wok hei* flavor are only an occasional order. The same dual-fuel strategy can be applied to restaurants that largely boil water, cook sauce, and otherwise heat ingredients in an even way but that also field occasional orders for flame-grilled or broiled meats. The Sacramento restaurant featured in Chapter 3 suggested adopting such a solution if it did electrify its kitchen such as using a specialized oven burning wood pellets to grill salmon and other meats.

Future research could expand this dual fuel concept to an entire region's energy system by studying the concept of parallel energy networks, with an abbreviated gas system that only serves restaurants needing natural gas as well as electricity and all other residences and businesses connected only to the electrical grid. Such a dual system runs counter to the common wisdom that electrification needs to be an all-or-nothing endeavor since keeping one customer on the gas system would require an equivalent amount of maintenance on that gas line as keeping all customers on the gas system. Other U.S. states, however, especially in the South, have achieved far higher levels of electrification than California, having seemingly figured out how to operate such parallel systems. For example, more than three-quarters of homes in Florida were powered only by electricity in 2020 compared to less than a fifth of homes in California. (U.S. Energy Information Administration, n.d.) Restaurants in Southern states, however, still principally use natural gas to run their kitchens, which points to the emergence of parallel systems with one system providing only electricity to most homes while a separate system supplies natural gas to restaurants. Perhaps California utilities can learn from the experience of these Southern states to operate a similar restaurant-only gas system, rather than wait for restaurants to get on board with electrification to advance larger electrification policies. As this research shows, some restaurants will never be able to completely electrify at least using current electric induction technology.

Limitations of Research

A chief consideration of this research was making sure to use the same or equivalent kind of electric induction equipment in kitchen experiments that would actually be installed in a restaurant to produce dishes at a commercial scale. The induction stovetops employed in this research were both mid-priced models that did not require being plugged into upgraded electrical panels of 240 volts or higher. Some higher priced commercial induction stoves do require higher voltage levels and are advertised as providing more heating power. That said, the Nuwave induction wok used in this research had a maximum temperature of 575 degrees Fahrenheit, which surpassed the maximum temperature of a much more expensive induction wok billed as commercial grade - the Spring USA SM-351WCR-6 MAX Induction wok. (Spring USA, n.d.)

Similarly, the Duxtop induction stove top has a maximum temperature of 460 degrees Fahrenheit, comparable to the maximum temperatures of commercial induction stovetop models such as the AT Cooker, which has a maximum temperature of 500 degrees Fahrenheit. (AT Cooker, n.d.)

Given those comparable heat ranges, the main limitation of this research didn't appear to be whether the induction equipment used could match the temperatures of the highest-end commercial stovetops. López-Alt's book suggests the limitation has more to do with the temperatures and heat fluxes achievable using any kind of induction stovetop. In *The Wok: Recipes and Techniques*, López-Alt documents quite different temperature fluxes when cooking with a flame-powered wok versus a flat-bottomed flame-powered skillet. Both cooking vessels start at 650 degrees Fahrenheit before ingredients are added, López-Alt found. The temperature in the wok then drops to 400 degrees Fahrenheit after ingredients are added, while the temperature in the skillet drops to only around 475 degrees Fahrenheit, with the differential caused by the thinner material of the wok allowing for greater temperature fluctuations. About a minute after ingredients are added, the average temperature in the skillet settles to around 500 degrees Fahrenheit while the average temperature in the wok plateaus at a higher 550 degrees Fahrenheit. (López-Alt, 2022) Based on this data, the Duxtop induction stovetop produced maximum temperatures 40 degrees below the average maximum cooking temperature of a flame-heated skillet. The Nuwave induction wok, however, produced maximum temperatures 25 degrees hotter than the average maximum cooking temperature of a flame-heated wok.

One note to these temperature measurements is that for gas-powered stoves, the temperature in the pan is far lower than the actual temperature of the flame, which can reach as high as 3,560 degrees Fahrenheit, given the pan's power to mediate the incoming temperature. Such differences are not applicable for induction stoves, since the stovetop itself produces no heat. All heat is generated by the pan itself receiving electromagnetic energy from the induction stove. In other words, the Nuwave wok's maximum temperature of 575 degrees Fahrenheit is the actual temperature in the pan. This phenomenon also points to the enormous amount of waste heat generated by gas-powered stoves with most of the flame's heat escaping into the environment, compared to the more efficient heating performance of induction stovetops. As a result, gas-powered kitchens need to spend more on kitchen cooling than electricity-powered kitchens need to spend to offset the flame-powered stove's waste heat raising temperatures throughout the kitchen. As noted in Chapter 4, that difference in waste heat emissions could represent ongoing savings in air-conditioning needs for electrified kitchens.

In summary, the induction stovetop and wok used in this research produced results comparable to those that would be generated by higher end

equipment at least in this limited application. More expensive commercial induction equipment is designed to perform high-powered cooking throughout the day as opposed to the mid-priced models used here that are designed for more limited residential applications. Future research could use the highest-end commercial equipment to see if the higher voltage levels significantly affected the end results in terms of crispiness, smokiness, and general *wok hei* flavor in stir-fries as well as noticeable differences in other dishes. Perhaps technical operating factors other than maximum temperature play more significant roles than accounted for here in generating the levels of dynamic heat needed to properly prepare stir-fries and other dishes the way consumers expect them to be prepared. Nonetheless, given the results of past research and the results obtained here, it appears that at least with wok cooking, even the most expensive induction model currently available cannot completely replace flame-based cooking methods.

Conclusion

As with most real-world policy and technical debates, the conclusions reached in this work paint a nuanced picture of the future of commercial kitchen electrification. When considering the different facets studied here - customer attitudes, kitchen practices, electrification costs, and the thermodynamic capacities of induction equipment - this work reveals trends in some areas and identifies other areas needing more investigation.

To start with, Part 1 of this work suggests that most customers have no inherent bias about eating at electric-powered kitchens although the majority of respondents also believed certain dishes needed to be cooked on flame to taste the way they are supposed to taste. Part 4 of this work supports that latter belief that flame is necessary for some dishes, at least when it comes to grilled foods and some stir-fries. Considered together, these results suggest that electric cooking can viably produce many types of dishes except for the dishes noted above. That opens up a big opportunity to electrify more restaurants at least in terms of customer acceptance of food cooked on electric equipment and the actual ability to cook certain foods on induction stoves.

The larger challenges to commercial kitchen electrification come out of Parts 2 and 3 of this work examining the economic costs of transitioning gas-powered to electric-powered cooking. The energy audit conducted at the Sacramento restaurant as well as other data suggest that the energy cost savings of electrification for most restaurants are just not great enough to pay for the high capital costs required to buy the new equipment much less the costs of upgrading electrical systems, buying new pots and pans, and retraining staff. On that last point, Part 2 of this work suggests that some amount of staff retraining will indeed be needed if a restaurant seeks to convert a gas-powered kitchen to all-electric commercial equipment. That all adds to the total cost of making such a change, with that up-front cost number proving to be an electrification deal-breaker at least for the Sacramento restaurant participating in the energy audit in Part 3 of this work.

For building decarbonizations researchers in general, this work argues that culture and values around food preparation and consumption should be top considerations, in addition to economic, technical, and other more quantitative factors, when considering the viability of commercial kitchen electrification. As this work has sought to demonstrate, the need to grow, prepare, and share food has helped determine how entire societies are organized and operated throughout human history. People are intimately connected with their culinary traditions - their "foodmaps" as Marte puts it - and proposals to alter those traditions will likely stir personal reactions. (Marte, 2007) Food also triggers associations with larger moral concepts such as purity, the

taboo, and personal refinement, as argued by Levi-Strauss and Douglas. Simply put, culture and values should play a central part of any electrification policy debate if the discussion is to be applicable to any socially relevant context.

Food, however, is not the only decarbonization pathway that can evoke personal reactions. One prominent example is transportation electrification, which touches upon the iconic role personal vehicles have long played in American culture. As food is more than just a means for sustaining people physically, cars are for many Americans more than just a manner of moving between points. They have historically represented values such as personal freedom, maturation into adulthood, adventure, and socioeconomic status. While electric cars may offer tangible benefits such as more responsive acceleration, lower fueling costs, and environmental sustainability, that may not be enough for many Americans if electric vehicles don't inspire the same feelings of freedom and social mobility that fossil fuel-powered cars do.

This is where energy mental models, folklore, and storytelling play an important role in developing decarbonization research strategies and policy applications. This work argues that the starting point for researchers and policymakers should include the core values and mythologies that the old and new technologies evoke for people. At least in an open democratic society, mandating solutions that conflict with such values will trigger pushback and limit the scalability of any solution. People will find ways to resist electrification mandates, whether it's simply ignoring the rules or turning to the courts or the political process to reverse tone-deaf laws. By definition, public policies are created to steer communities toward behavior they probably wouldn't otherwise adopt without those policies' coercive effects. Doing that effectively means at least first understanding why current practices have evolved to the point they've arrived at absent those policies and then identifying the points of greatest influence that those policies can exert on people's behavior.

Other fields of study have examined different ways to catalyze the urgent energy and decarbonization transition for more people, whether it's ensuring that electrical grids can handle the additional load generated from more all-electric homes or providing the economic incentives to help households and businesses pay for often expensive new clean energy technologies. This work argues that culture and values should be afforded equal weight in this decarbonization equation – a consideration that does not occur regularly currently in climate and energy policy. Perhaps this work's biggest contribution to the current discussion is to place the kitchen electrification debate in the context of the storied and vibrant anthropological and structuralist literature examining the role of food in shaping and enforcing household and societal values. This work argues that a restaurant owner considering electrifying their kitchen will consider the culinary cultural tradition they're working in as well as

the culinary expectations of their customers just as much as they will consider transition cost or grid capacity.

This work aims to demonstrate that this approach is not limited to commercial kitchens, and that the anthropological and possibly structuralist literature should be granted equal weight as economics, engineering, and other quantitative concerns in a range of energy transition and decarbonization work. The fields of anthropology and cultural studies, for example, have already explored topics such as the culture and values of automobiles or the folklore of coal miners and oil and gas industry workers in the United States as well as in other parts of the world. Policymakers and researchers seeking to reduce the pain points and bottlenecks for transitioning to zero-emission vehicles or renewable electricity generation can leverage that existing work to understand the often complex systems of political, cultural, and social dynamics at play in any one of these topics – dynamics that policymakers will likely encounter as they try to implement behavior change.

Energy transitions also take place in specific areas with their specific local cultures often determined by the energy-based economic activity dominant there. Kate Gordin, former senior advisor to Energy Secretary Jennifer Granholm, noted in a 2025 article titled "Managing the Energy Transition: A Place-Based Approach":

> *It's no surprise then that the relationship between these industries and the places they are located goes beyond job statistics and the economy—to the essential culture of the places. Jobs in extractive industries are often passed down from generation to generation. Because the towns grow up around the industry, the industry is infused into the towns. (Gordon, 2025)*

This research argues that central to understanding a place, be it a commercial kitchen or a whole state, is understanding its local culture as expressed in stories, art, narratives, religion, values, and other evidence of what people believe and how they live. As Gordon states in her piece, coal mining jobs in areas such as West Virginia with a long history of coal mining are part of "the essential culture of the places." That means that asking people there to give up that culture in favor of embracing solar, wind, and other renewable energy is to ask them to transform their cultures. This research argues that policymakers, business leaders, and clean energy advocates need to understand the original culture before making that ask.

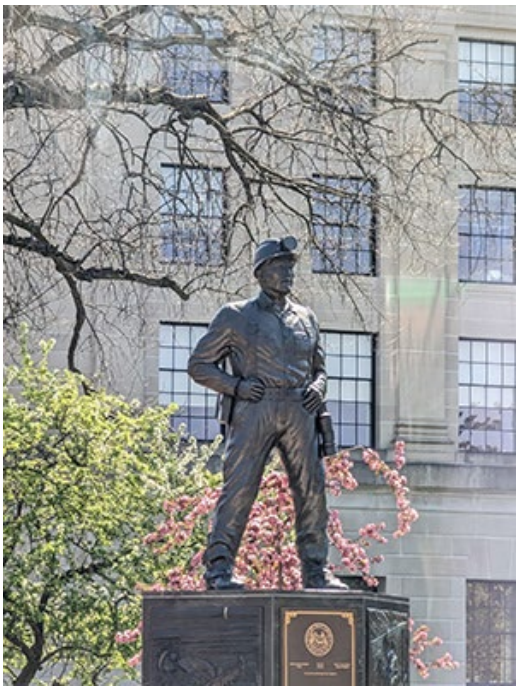


Figure 17: The West Virginia Coal Miner, a bronze statue by sculptor Burl Jones, on the grounds of the West Virginia State Capitol complex in Charleston, WV. (Source: Weila Gong and Poorva Kaushik)

This work also argues that this isn't a nice-to-have ingredient of policy analysis, but a core consideration for any decarbonization effort hoping to effect widespread behavior change across political, socioeconomic, and cultural categories. Decarbonization cannot be only the pursuit of one segment of society. It needs to become accessible to all segments of the Six Americas of Climate Change as defined by Yale Program on Climate Change Communications Director Anthony Leiserowitz and his colleagues in their groundbreaking study on climate science acceptance among the U.S. public. (Leiserowitz et al. 2014) Ranging from the alarmed who believe in the urgency of the climate crisis to the dismissive who actively discount the credibility of climate science, as many people as possible in the Six Americas need to adopt decarbonization solutions to complete this global transition. The research conducted here argues that in addition to lowering the cost of clean technologies and ensuring appropriate public infrastructure is available, shaping policies and communications to account for the values and narratives of diverse groups should be a core strategy for including all Six Americas in any decarbonization solution.

Communicating across the Six Americas could also help communicate across the entrenched partisan lines that have all but paralyzed the United States. And on no other issue are Americans more divided than the

environment, according to 2017 research by Patrick J. Egan of New York University and Megan Mullin of Duke University. On federal spending for eight high-level issues such as defense, poverty, and crime, the environment triggered the greatest difference of opinion between Democrats and Republicans in 2012 in American National Election Studies surveys, with Republicans less supportive of federal environmental spending than Democrats, Egan and Mullin found. That split widened dramatically after 1988, when the environment did not even rank among the top five most polarizing issues in surveys. (Egan & Mullin, 2017) It's likely that that divide has grown even wider, along with the overall fracturing of U.S. politics, in the subsequent 13 years.

Simply put, this finding is an out-and-out tragedy for the future of the earth and the people and other beings living on it. Avoiding climate disaster requires collective behavior change on a scale unprecedented in human history. Yet the issue has become the most divisive of all issues, at least in the United States. This research argues that this division on environmental issues must be recognized and addressed seriously if humanity is to have any chance at preserving a habitable planet.

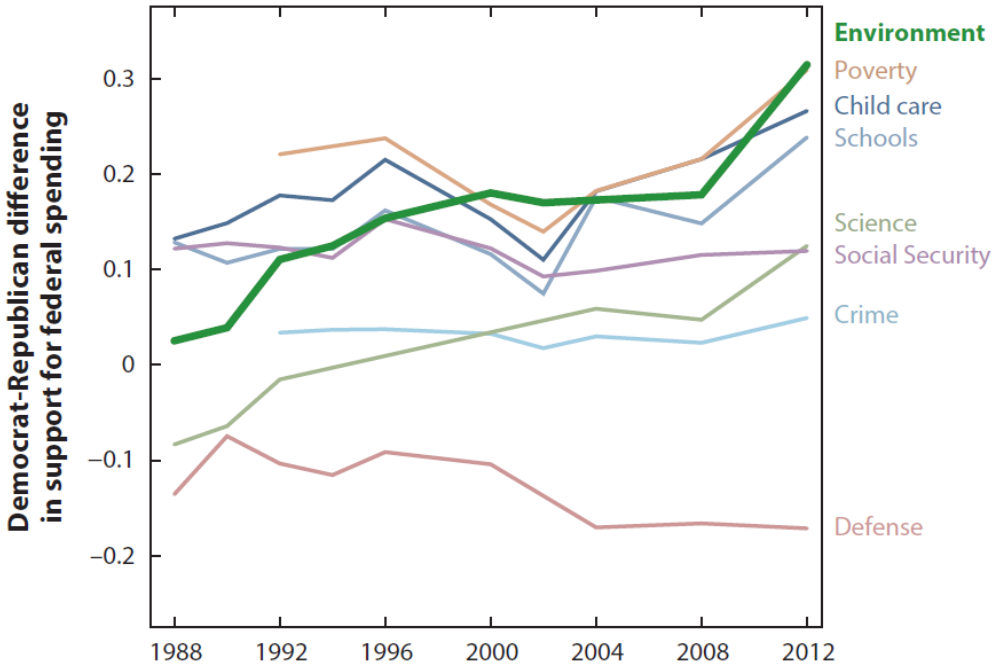


Figure 18: The environment was the most divisive issue among Republicans and Democrats in 2012 when they were asked how they would prioritize federal U.S. spending in American National Election Studies surveys. (Egan & Mullin, 2017)

As just one example of this divide, 2025 research by UC Berkeley professor Lucas Davis and his colleagues Jing Li and Katalin Springel found that electric

vehicle adoption is far higher in U.S. states and counties with a Democratic majority, with 34.2 percent of all electric car registrations occurring in the top 5 percent most Democratic counties in the United States from 2021 to 2023, and 21.9 percent of all electric truck registrations happening in those same counties during that same period. (Davis et al., 2025) The research controlled for other variables such as housing income, population densities, and gasoline taxes and found that none of those factors could explain the disparities in electric vehicle adoption. The paper concludes by finding "a strong and enduring correlation between political ideology and U.S. (electric vehicle) adoption." (Davis et al., 2025). At least in the United States, clean energy adoption must break through this partisan divide if it has any chance of achieving necessary levels of widespread adoption to significantly bring down greenhouse gas emission numbers. This work argues that focusing on culture and values in any energy transition effort is an important step to encouraging clean energy adoption by a wide swath of households and businesses.

Using this cost and culture lens for commercial kitchen electrification, this work suggests the points of greatest possible influence are with new restaurants that don't principally serve grilled or stir-fried foods. Such restaurants can actually save on capital costs when installing an electric-only kitchen compared to a gas-powered kitchen from the very start, and they will also likely pay lower energy costs if they're located in areas with high air-conditioning demand. (Synapse, 2018) Current induction cooking equipment can also serve most of these restaurants' cooking needs. This research suggests that the points of greatest resistance for electric kitchens will be in converting current gas-powered restaurants to electric induction cooking, especially if their menus are based on grilled and stir-fried foods that are culturally tied to flame cooking. The capital costs of making such a transition are currently financially prohibitive, and induction technology cannot produce the types of cooking needed for certain dishes, at least when using current induction technology. This could all change in the coming years if 1. the costs of induction equipment drop, likely due to scaled production and use, and 2. if the technology becomes technically capable of producing more dynamic heating processes such as heat spikes and locationally variable heat within the pan.

Technology does evolve quickly, so the time may soon come when an updated assessment will be needed for the capacities and costs of commercial kitchen electrification. For now, the path looks promising at least for phased restaurant electrification, starting with restaurants such as Homeroom and Franquette requiring only even, steady heat and progressively graduating to restaurants with more varied cooking demands. One day, electric induction stovetops could even power the kitchens of Noodle Fresh and C Casa if the price point and technology reach the right point to meet the expectations of customers and restaurants for certain culture-specific dishes. Implementing this

approach, however, would require giving up the all-or-nothing gas decommissioning strategy currently advocated by many in the building decarbonization movement. Instead, this transition could take a few more years of phased-in electrification to reach a critical mass where enough restaurants in an area have given up gas so that turning off entire gas system trunk lines doesn't cause massive business disruptions. In the meantime, opportunity awaits to electrify hundreds of restaurants in California and elsewhere already primed for change.

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Appendix A

ENCUESTA DE UC BERKELEY SOBRE PREFERENCIAS CULINARIAS

California está tratando de reducir las emisiones de gases de efecto invernadero incentivando la transición de gas natural a electricidad para calefacción y cocina. Esta encuesta intenta evaluar el impacto de las expectativas de los clientes de restaurantes en la preparación de su comida y las ambiciones medio-ambientales del gobierno de California, especialmente con respecto a los restaurantes interesados en usar exclusivamente cocinas eléctricas. Los resultados de esta encuesta forman parte de las investigaciones de energía renovable hechas por UC Berkeley, en particular sobre la electrificación de cocinas comerciales. Estaremos muy agradecidos si responde a las siguientes cinco preguntas:

P1: ¿Cuando piensa en sus platos favoritos, toma en consideración cómo se prepara la comida (grillada, hervida, frita), además de sus ingredientes? SÍ o NO

P2: ¿Es importante para usted cómo se prepara la comida en la cocina de un restaurante cuando decide en cuál restaurante va a comer? SÍ o NO

Si su respuesta es "SÍ" - ¿Qué es lo que le importa de la preparación de la comida en un restaurante?

P3: ¿Iría a comer a un restaurante que sólo usa cocina eléctrica? SÍ o NO

Si la respuesta es "NO" - ¿Qué le preocupa de los restaurantes que preparan sus platos sin fuego o gas natural, sólo con calor producido por electricidad?

P4: ¿En su opinión, existen platos que deben ser preparados exclusivamente con fuego para obtener un buen sabor? SÍ o NO

Si la respuesta es "SÍ" - ¿Cuales platos deben ser preparados solamente con fuego?

P5: ¿Ha usado una estufa de inducción eléctrica para cocinar? SÍ o No

Appendix B

UC BERKELEY FOOD PREFERENCE SURVEY DESCRIPTION:

加州大学柏克莱分校，烹调喜好意向调查：

California is trying to reduce greenhouse gas emissions by encouraging the transition from natural gas use to all-electric heaters and stovetops in buildings.

加州政府正在尝试鼓励人们在大楼及住房里从使用天然气转换到使用电暖器和电炉，以减少温室气体排放。

This survey aims to gauge how customer expectations about food preparation can impact these transition plans especially in restaurants looking to electrify their kitchens.

这份意向调查的目的是帮助餐馆衡量在转用电磁炉烹调时，顾客对餐馆菜馄饨口味的预期有无影响。

These survey results will be used in energy research based at UC Berkeley looking specifically at commercial kitchen electrification.

這份意向調查的結果將會用於以加州大學柏克萊分校為基地的能源研究，特別是在考慮商業廚房電氣化的可行性時。

Thank you for answering the following five sets of questions.

谢谢你回答下面的五个问题：

Q1: When you think about meals you like eating, do you consider the way in which they are cooked (i.e., grilled, boiled, fried. . .), in addition to what is in them? YES or NO

第一题：当你挑选餐点时，你会考虑食物的烹调方法吗？（**煎煮烤炸等**）：1）**会** 2）**不会**

Q2: Do you consider how food is cooked in a restaurant 's kitchen when you choose which restaurant to dine out in? YES or NO

第二題：當你知道餐館食物的烹調方法時，會影響你決定去外食還是在家吃飯嗎？ 1）**會** 2）**不會**

If Yes, what is important to you about how a restaurant cooks its food when choosing where to eat out?

如果你上面的回答是'会'的话，对你而言，选择去哪吃饭的主要因素是什么？

Q3: Would you have any hesitation eating at a restaurant that only used electric, non-flame-based cooking? YES or NO

第三题：如果一个餐厅只用电磁炉烹调，而不用明火烹煮，会让你对去那家餐厅吃饭有所犹疑吗？ 1）**会** 2）**不会**

If Yes, what would be your concern about eating at an all-electric restaurant?

如果你上面的回答是'会'的话，你的考量因素是什么？

Q4: Are there any foods that you think can only be cooked on flame to taste good?

YES or NO

第四题： **是不是有些菜餚你**觉得一定要用明火烹调才会好吃呢？

1）**是** 2）**不是**

If Yes, which foods? **如果是，是什么菜餚？**

Q5: Have you ever cooked on an electric induction range? YES or NO

第五题：你有用过电磁炉烹调吗？ 1）**有** 2）**没有**