

Feasibility Study on Application of Electric Stove in Civil Kitchen

-- Comprehensive Evaluation Based on Thermal Efficiency Measurements and Ozone Emissions

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Abstract: As urban gas adoption approaches saturation and electrification of household appliances accelerates, electric cooktops—a novel plasma cooking device—are gaining traction in residential kitchens. This study systematically evaluates thermal efficiency, heat load stability, and operational safety of two electric cooktop models (Xingyu YN-XY-0001-A and Huahuo HH-DTQP5 Pro) through comparative tests with traditional gas stoves. Results reveal that electric cooktops demonstrate lower thermal efficiency (57.4%) at low power levels compared to gas stoves (64.6%), though significant efficiency improvements occur in medium-to-high power ranges. Actual heat load measurements consistently fall below rated power output, indicating energy conversion losses. Notably, ozone emissions generated by corona discharge during operation can now be effectively mitigated through electrode structure optimization and UV decomposition systems. Comprehensive techno-economic analysis indicates potential for electric cooktops in gas-free areas, newly electrified communities, and scenarios requiring open flame cooking. However, ozone control mechanisms and thermal efficiency enhancement remain critical barriers to large-scale commercial adoption.

Keywords: Electric fire stove, Plasma combustion, Thermal efficiency, Ozone emissions, Civil feasibility.

1. Introduction

By 2025, the urban gas penetration rate in China has exceeded 98%, and natural gas has basically established its position as the core energy source for civilian cooking [8]. However, driven by the dual goals of "dual carbon" and the electrification of terminal energy, new electric heating cookware is reshaping the kitchen energy structure. Electric flame stoves (also known as electric flame cookers), as innovative products based on plasma technology, directly convert electrical energy into open flames through high-voltage arcs, achieving cooking experiences similar to traditional gas stoves without relying on fossil fuels [1][4].

Existing research has addressed the techno-economic aspects of electric stoves. Chen Xue et al. (2025) conducted a preliminary comparison between electric and gas stoves from perspectives of thermal efficiency, energy consumption costs, and safety, highlighting the potential for electric stoves to replace gas stoves in specific scenarios [4]. Cai Yu (2025) further analyzed the plasma technology principles of electric stoves and their compatibility with gas pipeline networks, concluding that while gas stoves maintain technological and economic advantages, electric stoves can serve as supplementary options for particular applications [8]. However, most of these studies rely on theoretical derivations or manufacturer data, lacking independent field validation, and pay insufficient attention to ozone emissions generated during electric stove operation.

This study utilizes field measurement data from two mainstream electric cooktop models, Xingyu and Huahuo,

combined with comparative experiments using traditional gas cooktops. It conducts quantitative analysis across three dimensions: thermal efficiency, thermal load stability, and safety risks (particularly ozone emissions). The objective is to provide empirical evidence for the feasibility of electric cooktops in residential applications and to offer references for subsequent technological improvements and standardization efforts.

2. Experimental Methods and Data Sources

2.1. Thermal Performance Testing of Electric Stoves

This study selected two electric cooktops, Xingyu YN-XY-0001-A XY-PY 702 (nominal power 3000W) and Huahuo HH-DTQP5 pro (nominal power 3000W), for thermal performance testing. The tests were conducted under standard laboratory conditions (room temperature 14–25°C, atmospheric pressure 101.44–102.48 kPa), employing the water calorimeter method to determine thermal efficiency and heat load.

The test conditions were divided into three levels: low power (1500W), medium power (2200W), and high power (3000W). Each condition group included three repeated experiments to measure the power consumption and heating time when water temperature increased from 25°C to 50°C and from 50°C to 75°C. The arithmetic mean was calculated to determine thermal efficiency and thermal load (see Tables 1 and 2).

Table 1. Thermal load and thermal efficiency of Xingyu electric stove at different power levels

XingYu-YN-XY-0001-A XY-PY 702 (3000w, 220v, 50hz)							
Underpower (1500w, 220v)							
	25°C	T	50°C	T	75°C	Thermal efficiency	Thermal load
Group 1	10.74kw.h	10'1"36	10.99kw.h	10'07"35	11.24kw.h	57.40%	0.85kw
Group 2	11.49kw.h	10'47"25	11.75kw.h	10'53"10	12.02kw.h		
Group3	12.17kw.h	9'29"62	12.40kw.h	10'18"27	12.68kw.h		
Mean value	11.47kw.h	10'10"08	11.71kw.h	10'26"12	11.98kw.h		
Medium power (2200w, 220v)							
	25°C	T	50°C	T	75°C	Thermal efficiency	Thermal load
Group 1	11.02kw.h	5.50.76	11.25kw.h	6.22.51	11.48kw.h	60.80%	1.43kw
Group 2	11.62kw.h	5.53.88	11.86kw.h	6.25.66	12.09kw.h		
Group 3	12.68w.h	5.52.56	12.90kw.h	6.24.77	13.14kw.h		
Mean value	11.77kw.h	5.52.40	12.00kw.h	6.24.31	12.24kw.h		
High power (3000w, 220v)							
	25°C	T	50°C	T	75°C	Thermal efficiency	Thermal load
Group 1	3.184kw.h	5'04"15	3.434kw.h	5'04"06	3.698kw.h	55.00%	1.66kw
Group 2	4.055kw.h	5'07"00	4.312kw.h	5'17"00	4.584kw.h		
Group 3	4.990kw.h	5'06"17	5.239kw.h	6'00"17	5.544kw.h		
Mean value	4.08kw.h	5'05"77	4.33kw.h	5'27"08	4.61kw.h		

Table 2. Thermal load and thermal efficiency of Huahuo electric stove at different power levels

HuaHuo-HH-DTQP5 pro (3000w, 220v, 50hz)							
Underpower (1500w, 220v)							
	25°C	T	50°C	T	75°C	Thermal efficiency	Thermal load
Group 1	7.380kw.h	12'14"74	7.673kw.h	13'25"	8.002kw.h	48.10%	0.69kw
Group 2	8.159kw.h	12'05"	8.449kw.h	12'35"	8.754kw.h		
Group 3	8.835kw.h	12'32"	9.127kw.h	12'46"	9.442kw.h		
Mean value	8.124kw.h	12'17"	8.416kw.h	12'55"	8.732kw.h		
Medium power (2200w, 220v)							
	25°C	T	50°C	T	75°C	Thermal efficiency	Thermal load
Group 1	8.953kw.h	7.47.50	9.234kw.h	7.46.97	9.511kw.h	51.70%	1.12kw
Group 2	9.612kw.h	7.47.39	9.859kw.h	7.46.86	10.174kw.h		
Group 3	10.213kw.h	7.47.88	10.494kw.h	7.47.15	10.77kw.h		
Mean value	9.593kw.h	7.47.59	9.862kw.h	7.46.99	10.152kw.h		
High power (3000w, 220v)							
	25°C	T	50°C	T	75°C	Thermal efficiency	Thermal load
Group 1	5.925kw.h	5'32"	6.193kw.h	5'33"	6.471kw.h	55.50%	1.59kw
Group 2	6.665kw.h	5'27"	6.915kw.h	5'34"	7.189kw.h		
Group 3	7.235kw.h	5'29"	7.486kw.h	5'32"	7.729kw.h		
Mean value	6.608kw.h	5'29"	6.865kw.h	5'33"	7.129kw.h		

2.2. Control Experiment for Gas Stoves

The control experiment employed a propane gas stove (calorific value 1404.34 kJ/m³), with gas flow meter correction coefficient K=1.01 and volumetric conversion coefficient f=0.970, conducted according to the "Method for Determination of Thermal Performance of Gas Stoves." The

test was repeated twice, and the average value was taken as the baseline reference.

The experiment also referenced historical data from artificial gas stoves (low calorific value of 1416 kJ/m³, volume conversion factor of 1.03) for supplementary validation (see Table 3).

Table 3. Data on Artificial Gas and Coke Oven Gas

	number of times	first	second time	third time	first	second time	third time
	Determination of Heat Load of Stove	Flow meter reading/L	70	73	71.5	10	10
testing time /s		280	295	287.5	119	121	120
Gas consumption rate/m ³ /s		0.00025	0.00025	0.00025	0.000084	0.000083	0.000083
Heat load of stove/kW		3.406	3.406	3.406	1.16	1.16	1.16
Determination of Heat Efficiency of Stove Appliances	Diameter of pot/mm	300	300	300	300	300	300
	Temperature increase/°C	30	30	30	50	50	50
	Consumed gas volume/m ³	0.070	0.073	0.0715	0.132	0.132	0.132
	Heat efficiency of stove	65.857%	63.315%	64.586%	56.74%	56.74%	56.74%
Gas type	coal oven gas				Artificial gas		
Low calorific value of gas	14044.34KJ/m ³				14261.16KJ/m ³		
room temperature	12.3°C				14°C		
atmospheric pressure	102.48kPa				101.66kPa		

3. Empirical Analysis of Thermal Efficiency and Thermal Load

3.1. Power Dependence of Thermal Efficiency for Electric Stoves

Experimental data demonstrate a significant nonlinear

relationship between thermal efficiency and input power for electric cooktops. The Xingyu electric cooktop achieves a thermal efficiency of 57.4% at 1500W, rises to 60.8% at 2200W, and slightly decreases to 55.0% at 3000W. The Huahuo electric cooktop exhibits similar patterns: thermal efficiency of 48.1% at 1500W, 51.7% at 2200W, and 55.5% at 3000W (see Figures 1 and 2).

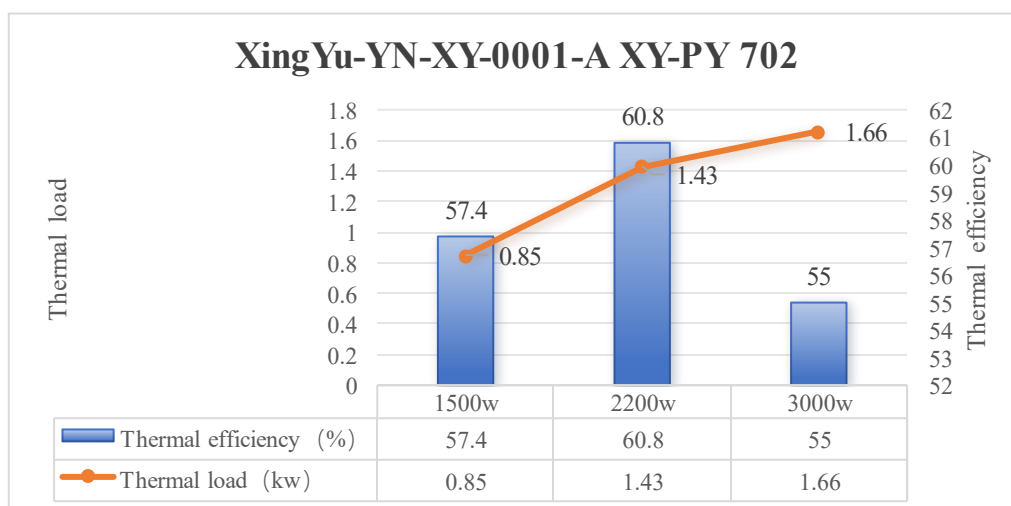


Figure 1. Linear relationship between thermal efficiency and output of Xingyu electric stove

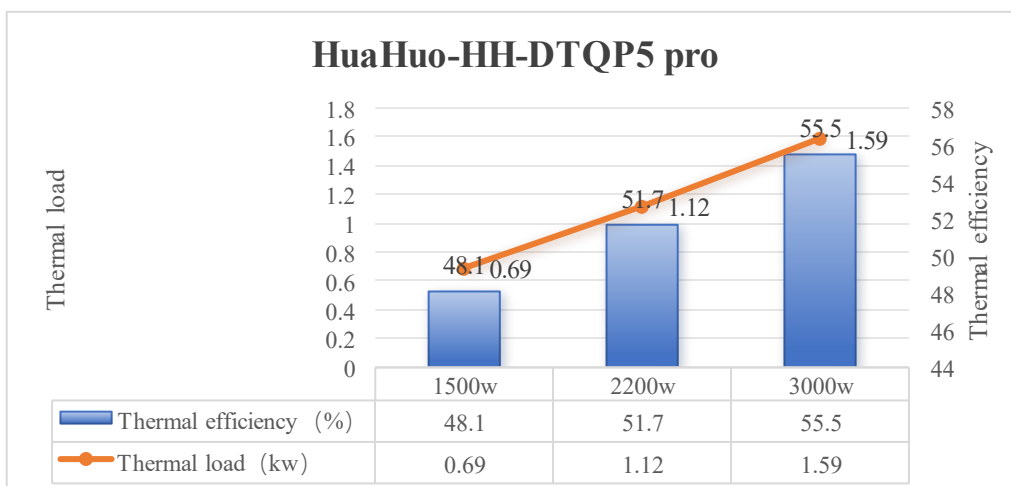


Figure 2. Linear relationship between thermal efficiency and output of Huahuo electric stove

This phenomenon can be explained through the physical mechanisms of plasma combustion. Under low-power

conditions, the arc energy density is insufficient to maintain a stable plasma sheath, with partial energy dissipated as Joule heat within the electrodes rather than being transferred to the heating element, resulting in low thermal efficiency. As power increases, the arc coverage area expands and temperature distribution becomes more uniform, leading to corresponding improvements in thermal efficiency. However, when power exceeds a critical threshold (approximately 2200W), intensified electrode overheating and convective heat loss exacerbate the situation, causing marginal efficiency decline or even a decrease in thermal performance.

Comparative data with gas stoves shows that propane gas stoves achieve a measured thermal efficiency of 64.6% (at 30°C temperature rise conditions), while manufactured gas stoves reach 56.1% (at 50°C temperature rise conditions). In low-power ranges, electric fire stoves demonstrate thermal efficiencies (57.4% vs. 48.1%) comparable to or slightly lower than gas stoves (56.1%–64.6%). However, in medium-to-high power ranges, electric fire stoves can achieve thermal efficiency levels equivalent to gas stoves (60.8%–55.5%). Notably, Wang Lin et al. (2025) found that hydrogen-blended natural gas stoves exhibit increasing thermal efficiency with higher hydrogen blending ratios, peaking at 25% hydrogen content [3]. This indicates that electric fire stoves now possess competitive thermal efficiency capabilities with optimized gas stoves under medium-to-high power operating conditions.

3.2. Nominal vs. Measured Deviation of Thermal Load

There exists a systematic deviation between the measured thermal load and nominal power of electric cookers. The Xingyu electric cooker, rated at 3000W, showed measured thermal loads of 0.85kW at 1500W setting, 1.43kW at 2200W setting, and 1.66kW at 3000W setting. The Huahuo electric cooker, also rated at 3000W, recorded measured thermal loads of 0.69kW at 1500W setting, 1.12kW at 2200W setting, and 1.59kW at 3000W setting.

The aforementioned deviations reflect inherent characteristics of energy conversion efficiency in electric cooktops. The "nominal power" refers to the input power from the power supply, while the "thermal load" denotes the actual heat power transferred to cooking utensils. The difference between these two values represents system losses (including circuit losses, Joule heat losses from electrodes, and convective heat dissipation). Taking the Huahuo 3000W model as an example, with an input power of 3.0kW and measured thermal load of only 1.59kW, the energy conversion efficiency reaches 53.0%. Although this metric differs from the definition of thermal efficiency, both indicators consistently indicate the same conclusion: electric cooktops exhibit significant energy conversion losses.

From the user's perspective, this discrepancy implies that the perceived "heat output" of electric stoves may deviate from their rated power. If users expect the equivalent heat output of a 3 kW gas stove based on the 3000 W rated value, their actual experience may only match that of a 1.6 kW gas stove. This information asymmetry may affect product acceptance and user satisfaction.

4. Safety Risks: Mechanism of Ozone Emission Generation and Control Pathways

4.1. Physical and Chemical Mechanisms of Ozone Formation

During the experiment, a distinct ozone odor was observed during the operation of the electric stove. This phenomenon originates from the inherent physical processes of plasma combustion: under high voltage, the electrode tip forms a strong electric field region where oxygen molecules undergo ionization and dissociation, generating oxygen atoms and excited oxygen molecules, which subsequently undergo trinity collision reactions to produce ozone [2] (O_3).

Existing patent literature explicitly states that traditional electric flame stoves employ anode needles with sharp tip structures. According to the tip discharge principle, charges accumulate at the needle tip, creating localized strong electric fields that significantly enhance the excitation and ionization reactions of oxygen molecules, thereby generating ozone emissions [2, 9]. The severity of this issue lies in the fact that ozone is a potent oxidant with irritant and damaging effects on the human respiratory system and eyes. Prolonged exposure may lead to health problems such as respiratory inflammation and decreased lung function [2].

4.2. Technical Solutions and Efficacy Evaluation

To address ozone emission issues, existing technologies have proposed two solution approaches. The first involves optimizing electrode structures: modifying anode needle tips into rounded shapes to reduce electric field concentration, resulting in more uniform field distribution and thereby minimizing ozone generation reactions triggered by localized high electric fields [2]. The second approach focuses on exhaust gas treatment: installing ozone decomposition chambers within cooking appliances where ultraviolet modules irradiate exhaust gases, decomposing ozone into conventional oxygen for emission [9].

Some patents also propose introducing trace water molecules into the arc region, where electrolysis generates hydrogen gas that reacts with ozone combustion to further reduce ozone leakage [2]. However, this approach increases system complexity and manufacturing costs, and hydrogen, as a flammable gas, poses additional safety hazards in kitchen environments.

Comprehensive evaluation indicates that electrode structure optimization and ultraviolet decomposition represent the most feasible approaches for ozone control. The former reduces ozone generation at the source, while the latter eliminates existing ozone at the end-of-pipe stage, with both methods capable of synergistic application. It should be noted, however, that most of these technical solutions remain in patent stages, and their full commercial applicability requires independent validation [5].

5. Future Development Trends and Civil Feasibility of Electric Stoves

5.1. Direction of Technological Evolution

The technological advancement of electric cooktops will focus on three core directions. First, thermal efficiency improvement. Current electric cooktops still have significant

room for enhancement in thermal efficiency (48%-57%) under low-power operation conditions. Drawing from numerical simulation studies of household gas stoves, thermal efficiency can exceed 70% through optimized burner structure and airflow organization [4, 10]. Electric cooktops could adopt similar approaches by refining electrode layouts and implementing technologies such as swirl air supply to improve energy transfer efficiency.

Secondly, standardized regulation of ozone emissions. Currently, there are no mandatory national standards for ozone emissions from electric cooktops. Drawing on research on commercial kitchen equipment, future residential standards may require ozone concentrations not exceeding 0.1 ppm (8-hour weighted average exposure limit) [9]. The key to meeting technical requirements lies in transitioning electrode optimization and exhaust gas treatment technologies from patents to mass-production solutions.

Thirdly, interaction between intelligence and power grids. As pure electric devices, electric stoves inherently possess the potential to interact with smart grids. Through power regulation and load scheduling, electric stoves can store heat during off-peak electricity hours and reduce power consumption during peak hours, providing a new controllable load for household energy management.

5.2. Scenario-based Assessment of Civil Feasibility

Based on field measurements and technical analysis, the feasibility of electric stoves for civilian use cannot be generalized but must be evaluated within specific application scenarios.

The first category of scenarios involves areas without natural gas pipeline coverage. Some old urban districts, rural regions, and newly constructed remote communities in China have not yet been connected to natural gas, with residents relying on liquefied petroleum gas (LPG) cylinders or induction cookers. Electric stoves exhibit significant substitution advantages in such scenarios: no need for gas pipeline construction, absence of gas leakage risks, and energy consumption costs linked to electricity prices [1, 7, 8].

The second scenario involves the construction of fully electrified communities. Driven by the "dual carbon" policy, some cities have explicitly eliminated gas pipeline installations in new residential projects, adopting electric cooking equipment throughout. The core advantage of electric stoves over induction cookers lies in the "open flame cooking experience," which demonstrates higher acceptance among users accustomed to gas stoves [7].

The third category of scenarios involves the electrification retrofitting of commercial kitchens. Due to fire safety regulations, the use of gas fuels is prohibited in certain commercial kitchens. Existing patents have developed specialized ozone suppression technologies for commercial electric flame stoves, indicating that the application of this technology in commercial settings is gaining momentum [9].

5.3. Restraining Factors and Policy Recommendations

The large-scale commercialization of electric cookers faces three major constraints. Firstly, there exists a gap between the measured thermal efficiency and heat load values and user expectations. The manufacturers' claimed "thermal efficiency exceeding 75%" [1] shows significant divergence from the study's measured data (maximum 60.8%), which may stem

from differences in testing conditions and product models, but also reflects information asymmetry caused by the lack of industry standards. It is recommended to establish a unified energy efficiency labeling system for electric cookers, mandating the disclosure of measured heat load and thermal efficiency values.

Secondly, there is a lack of regulatory basis for ozone emissions. Current standards such as the "Household Gas Stoves" (GB 16410) do not apply to electric stoves, and there are no clearly defined limits for ozone emissions. It is recommended to establish ozone emission limits and testing methods for electric stoves by referencing indoor air quality standards.

Thirdly, installation constraints. Electric stoves generally have a power rating exceeding 2000W, requiring dedicated wiring with a cross-sectional area of at least 4 mm², and necessitating staggered usage with high-power appliances such as electric water heaters and air conditioners [1]. Circuit modifications in older residential buildings may increase installation costs and should be incorporated into comprehensive economic evaluations.

6. Conclusion

Based on field measurement data and theoretical analysis, this study concludes the following feasibility findings regarding the application of electric cooktops in residential kitchens:

First, the thermal efficiency of electric stoves exhibits power dependence. Under medium-to-high power conditions (2200W–3000W), it can reach 55%–61%, which is comparable to that of gas stoves. However, the thermal efficiency is relatively low at low power conditions (48%–57%), indicating room for improvement.

Secondly, the actual measured heat load of electric stoves is significantly lower than the rated power, with an energy conversion efficiency of approximately 50%–55%. Users should determine the heating capacity based on the measured heat load rather than the rated power when making selection.

Thirdly, ozone emissions generated during the operation of electric stoves due to the principle of tip discharge pose potential risks to human health. Existing technologies can achieve effective control through electrode structure optimization and ultraviolet decomposition, but the establishment of unified product standards and regulatory mechanisms is required.

Fourth, electric stoves demonstrate substitution potential in areas without gas pipeline networks, newly constructed fully electrified communities, and scenarios with rigid demand for open flames. However, ozone control and thermal efficiency improvement remain critical prerequisites for their large-scale application.

In conclusion, electric cooktops as a new energy terminal for residential kitchens have achieved preliminary technical feasibility. However, their large-scale adoption still requires three key supports: standardized regulations, technological optimization, and user awareness.

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