Residential Cooking IAQ Special Report:
Cooking Emissions for Natural Gas, Propane
and Electric Range Tops

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Summary

Recent reports and information presented by some universities, media outlets and other research organizations have raised questions about using natural gas or propane as the primary energy source for residential cooking in terms of safety and environmental issues. Many of these sources conclude that more research is needed to draw definitive conclusions for the claims being made. GTI Energy tested one claim that electric ranges have lower cooking emissions than natural gas[1]. For this study, cooking emissions is defined as only the emissions from the food during the cooking process and not the combustion emissions from the heat source. Based on the range top cook test developed by GTI Energy, and the tests conducted with natural gas, propane and electric range tops; a conclusion that one energy source generates more cooking emissions than the others cannot be made despite GTI Energy's results showing electric ranges emitted more cooking emission than natural gas or propane. Results showed cooking emissions were more a function of the cooking vessel and food product cooked than energy source. The results varied with different boxes of same food product and with the age of the food. The temperature control and temperature distribution of the pan's cooking surface was also shown to affect the cooking emissions generated. In the tests conducted by GTI Energy, the temperature varied more for the electric range and was more difficult to control than natural gas or propane.

Results showed that cooking emissions as a function of the fuel source are not well understood and require additional testing and evaluations with other range designs and food types to make definitive conclusions.

Cooking Emission Collection System and Test Design

The cook tests were conducted in the Residential Kitchen Ventilation test lab at GTI Energy using a gas range and an electric range. The gas range was chosen based on its typical design and popularity and the electric range was chosen based on it being the closest equivalent to the gas model in terms of cost and cooking compatibility.

A test plan was developed based on an updated standard being developed by Frontier Energy for ASTM F26 (https://www.astm.org/COMMITTEE/F26.htm). ASTM F1521-12 defines the pan, cooking procedures and food product to use during the testing, including 80% lean / 20% fat ¼ pound hamburgers. The biggest issue with measuring cooking emissions was developing a method to collect and measure the particulate matter (PM) emitted. The plume velocity was measured, and an isokinetic collection nozzle was used as the collection inlet for a personal cascade impactor loaned to GTI Energy from the University of Minnesota. It was the same instrument used in ASHRAE research project RP-745 by Gerstler et al[2] to measure particulate from cooking processes. The cascade impactor has 9 stages.

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1 Seals, B., Krasner, A., Health Effects from Gas Stove Pollution, Report from Rocky Mountain Institute, Mothers out Front, Physicians for Social Responsibility & Sierra Club, 2020.

2 Gerstler, W.D., T.H. Kuehn, D.Y.H. Pui, J.W. Ramsey, M.J. Rosen. R.R. Carlson, and S.D. Peterson. Identification and characterization of cooking effluents as related to optimum design of kitchen ventilation systems. ASHRAE Research Project RP-745 (Phase II), Final Report, 1998.

Each stage used a Tisch Substrate to capture different particles sizes based on volumetric flow and the stage number. The final stage used an absolute filter to collect the remaining particulate matter. The end of the impactor was connected to a flow gauge that is connected to a vacuum pump.

Figure 1. Residential Kitchen Ventilation test lab at GTI Energy (Gas Range)

Figure 2. Cooking Emissions Collection System

A flat stainless steel frying pan[3] had a thermocouple welded to the outer edge of the flat plate inside the pan to monitor the temperature of the cooking surface during testing to maintain a temperature of 350 °F. Each burger used for the test was frozen and never thawed. Each side of the burger[4] was cooked for 3 minutes and then removed from the frying pan. After each burger is cooked, the frying pan was scraped, cleaned, and brought back to cooking temperature within one minute. During the cook test, the burger was placed on the pan undisturbed including not adding pressure or stirring the pan. For each test, 10

3 10” stainless steel, 2 ± 0.2lb, Calphalon Classic Stainless Steel 10-Inch Fry Pan, Part # 1891245
4 80/20, 4:1’s, Sysco Foods product number 3480999

burgers were cooked (approximately 60 minutes total), and the cooking emissions were collected at a point 7 inches above the burger, which was located at the midpoint of the 14-inch cooking plume.

Prior to each test, the cascade impactor was washed and dried to remove any contamination. All Tisch substrates were dried for at least 24 hours before each test and absolute filters were placed in a desiccant chamber to remove moisture. The cascade impactor was assembled for testing by taking the filters and substrates out of the chamber, weighing each filter. After each filter was weighed, it was placed in the impactor with a substrate until the impactor was assembled. After each cook test, the impactor was removed from the collection system and placed into the desiccant chamber for 20 hours to dry out any moisture captured during the test. After 20 hours, the impactor was removed from the desiccant chamber and the weight of each filter was recorded.

Shakedown testing showed that cleaning was an important factor to keep tests independent of one another. After cooking, all utensils and cook surfaces and surroundings were cleaned of all grease. After all weights were recorded, the impactor was also cleaned.

Figure 3. Grease Accumulation During Testing

Cooking emissions tests were also attempted for the oven part of the range, but the emissions capture rate was too small to yield meaningful results.

Cooking Emission Results

Dozens of cook tests were conducted to develop a consistent method for measuring the cooking emissions. The measured weight gain per volume (mg/m^3) for the particulates emitted during cooking indicates electric cooking emits more particulates than natural gas or propane. The electric range had weight gains of 15.2 to 26.4 mg/m^3, the gas range had 7.1 to 8.2 mg/m^3 and propane had 4.7 to 5.9 mg/m^3. The results showed that values for the electric were consistently 2 to 3 times higher for the for measured weight gain. This result was consistent throughout testing. However, a conclusion that electric emits more cooking emissions than natural gas and propane does not definitively reflect the results of these tests. As was discovered during the testing, many factors contributed to the volume of cooking emissions generated. Reviewing the data discovered that different boxes of the same size and type of hamburger patties had slightly different levels of cooking emissions from the same energy source even though it was the same order number from the supplier. Also, the amount of time the hamburger patties were stored in the freezer at the lab influenced the cooking emissions. These factors are shown in the range of values for the weight gain per volume for the three energy sources. To a eliminate this variable, GTI Energy retested the natural gas and electric ranges in succession using the same batch of hamburger patties, but still recorded the same difference between the natural gas and the electric range.

However, during the testing GTI Energy discovered that the temperature distribution on the cooking surface, and the change rate of temperature of the cooking surface had the strongest effect on the cooking emissions generated. All standard methods for cooking performance in commercial foodservice specify the cooking temperature set point and how much that temperature can vary during the test. This is done because temperature fluctuations have a big impact on much energy is being used and the quality of the product being cooked. The electric range was more difficult to control and tended to drift more around the set point and was slower to respond to adjustments of the control knobs. The natural gas range had an average standard deviation from the set point of 5.8 °F compared to 9.7 °F for the electric. This type of temperature variation is known to have an effect on the final appearance or cook quality of the food and volume of emissions generated. The difference in temperatures is likely a function of the total energy input potential of the burners and the heat transfer mechanism between the heat source and the pan. The latter related to how a natural gas and propane range tops use both convection and conduction of heat on the pan while the electric range top is conduction.

Next Steps

Based on the GTI Energy's results and other studies of IAQ associated with residential cooking, more research is needed to accurately assess the impact cooking fuel source has on residential IAQ. Specifically:

- Quantification of how improved ventilation and improved oven burner technology in terms of efficiency and emissions could improve IAQ
- Acquisition of cooking emissions data for more range models, different burner or heating element designs and different food types
- Determination of how temperature fluctuations and distribution on the surface of cooking utensils affects cooking emissions
- Development of particulate distribution models based on data for generated cooking emissions

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