

# Food Service Building Asset Rating Methodology and Analysis

**Supriya Goel**

**Juan Gonzalez Matamoros**

**Alex Vlachokostas, PhD**

**Na Wang, PhD**

## **ABSTRACT HEADING**

*Food Service buildings are extremely energy intensive, using about 5 to 7 times more energy per square foot than conventional commercial buildings. Energy intensive commercial kitchen appliances are the primary drivers, often necessitating high exhaust air requirements. Currently, no standardized method exists to directly compare energy efficiency between different Food Service buildings. Different restaurant types have various types of appliances and cooked food throughput requirements and thus it is challenging to make direct comparisons. Past attempts to categorize Food Service use types into “Quick-Service” and “Full-Service” led to the development of the Standard 90.1 prototype building models. However, these models do not address the highly diverse Food Service use types. This paper proposes a methodology to compare Food Service buildings through an asset rating system. By identifying all unique systems in a kitchen and creating a common baseline, this methodology identifies approaches for normalizing variations in kitchen requirements and to compare all Food Service buildings against one another.*

## **1. INTRODUCTION**

The commercial Food Service industry uses approximately five to seven times more energy per square foot than other commercial buildings. Niche Food Service categories, such as high-volume Quick-Service Restaurants (QSRs), may even use up to 10 times more energy per square foot than other commercial buildings (EnergyStar 2017). The Food Service industry energy use is largely driven by the energy consumption of commercial grade cooking equipment, refrigeration equipment and high exhaust and ventilation requirements. Commercial kitchens are equipped with diverse appliances and refrigeration equipment, based on the type and quantity of food cooked. The operating schedules can also be highly diverse resulting in significant variations in their measured energy use. All of these variations make it highly challenging to develop an Asset Rating metric for Food Service buildings. This paper presents a methodology developed for the Building Energy Asset Score tool (hereafter referred to as the “the tool”) which implements a baseline that normalizes for primary energy sources of variations in commercial kitchens, such as appliances, ventilation and exhaust requirements, and operation assumptions. The methodology provides a standard baseline against which various Food Service buildings can be evaluated.

## **2. THE TOOL**

The web-based tool helps building owners, operators, and tenants understand the current and potential performance of a building asset. The building assets are defined as the building systems that are not influenced by

operational changes (e.g., envelope, mechanical systems, and electrical systems). The tool is based on a 10-point scale, with 0.5 point increments, where a higher score translates to a more efficient building asset, relative to its population of peers (Wang et al. 2016a). The tool is modular in design for clean separation of functionalities and easier development and testing. The backend simulation process is integrated within a framework to perform a sensitivity and energy use intensity (EUI) distribution analysis (Wang et al. 2016a, Wang et al. 2017). It leverages OpenStudio (OpenStudio 2017) and EnergyPlus (Crawley et al. 2000, EnergyPlus 2017) to calculate building energy use.

The tool is built on a simplified user interface, through which a user can specify key characteristics of the building, including but not limited to roof, walls, windows, lighting systems, heating, ventilation, and air conditioning (HVAC) systems, and the service hot water system. The tool standardizes for the plug and process loads and uses standard operating assumptions including schedules of occupancy, lighting, and thermostat setpoints. Once the building is scored, the user can download a PDF report which identifies the current score for the building, the potential score and a list of cost effective upgrade opportunities that the tool identifies through a series of optimization runs (Wang et al. 2016b). The tool can evaluate a large number of use types including multifamily, offices, retail, assisted living, city hall, community centers, courthouse, educational, etc. as well as mixed use buildings. This paper presents the methodology incorporated in the tool in order to evaluate the Food Service use type buildings.

## **2.1. Evaluating Commercial Kitchens Using the Tool**

The Energy Information Administration (EIA) characterizes Food Services as the most energy intensive use type in the United States based on energy per area, consuming more energy per square foot than an average commercial building (EIA 2017). Commercial kitchens have high electric and gas equipment densities for refrigeration, food preparation, and dishwashing, and often require high ventilation requirements. The internal loads in commercial kitchens can vary tremendously depending on the types and amounts of food served. The high energy intensive cooking equipment, long operation hours, high cooked food throughput, ventilation and cooling load contribute to considerable high energy use intensity. The evaluation approach implemented in the tool standardizes for these variations, enabling comparison and rating of Food Service buildings with different profiles of energy consumption and operation against each other.

The standardized baseline has been developed using the ASHRAE Standard 90.1 prototype building models developed by Pacific Northwest National Laboratory (Thorton et al. 2011). The prototype buildings represent 80% of the commercial building floor area in the United States for new construction, including both Quick-Service Restaurant and Full-Service Restaurants and provide a reference benchmark for developing a normalization approach for evaluating Food Service buildings. The rating methodology defines assets to include the cooking and refrigeration equipment, the heating, ventilation, and air conditioning systems (HVAC), exhaust hoods and system controls. A normalized baseline commercial kitchen is developed, against which all comparisons are drawn for scoring of buildings.

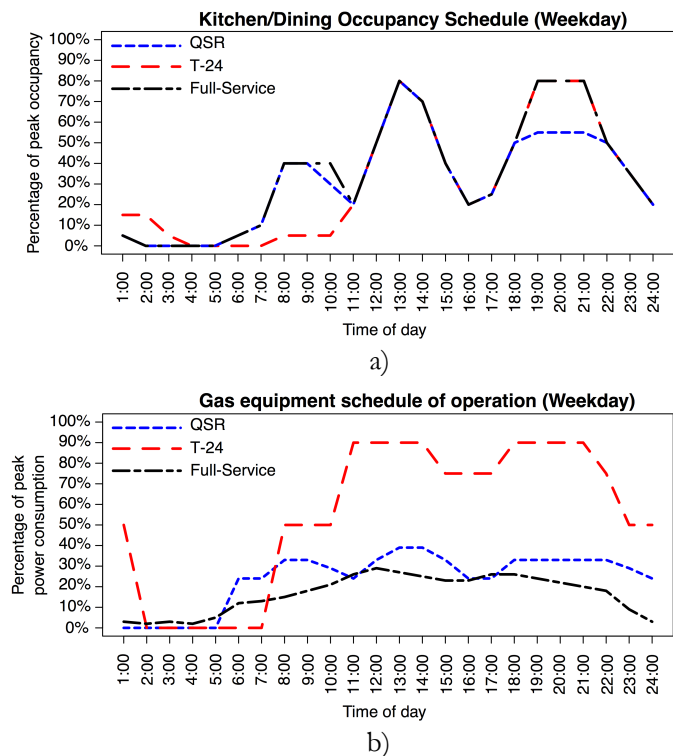
## **3. COMMERCIAL KITCHEN BASELINE DEVELOPMENT**

To evaluate commercial kitchens using our tool, extensive research was carried out to identify a standard set of schedules and loads that could be used to define a benchmark against which all buildings would be evaluated. These include schedules of operation (such as occupancy, lighting, thermostat setpoints, appliance operation, etc.), typical appliances and their input power rating, commercial kitchen ventilation requirements and strategies for energy savings.

### **3.1. Identifying Standard Operations**

The tool uses standard operating assumptions for schedule of occupancy, lighting, plug load operation, HVAC system operation and thermostat setpoints. This enables the comparison of buildings having varying schedules of operation. For analysis of the Food Service use types, several references were evaluated to determine kitchen

operation including California Energy Commission’s Title-24 (T-24) (CASE 2013), PNNL prototype buildings (DOE 2017), and the baseline model developed for the Advanced Energy Design Guides (AEDG) Quick-Service Restaurant (QSR) (Zhang et al. 2010). A comparison of the operation schedules is shown in Figure 1(a) and 1(b). The occupancy schedules for the three reference sources are very similar, where peak occupancy is observed around noon and 7 pm. However, the fractional schedules for gas appliances (Figure 1(b)) have significant variations between the three sources, where T-24 has peak appliance operation almost throughout the day, whereas both QSR and prototype has part load performance throughout the day.



**Figure 1** a) Occupancy schedule and b) gas equipment schedule for kitchen/dining.

In addition to the considerations associated with these schedules, the appliance W/ft<sup>2</sup> as modeled by the AEDG QSR and prototype buildings is 170 W/ft<sup>2</sup> and 100 W/ft<sup>2</sup>, respectively. The internal load recommended through T-24 is 10 W/ft<sup>2</sup> (CASE 2013). The recommended T-24 load was significantly low in comparison to AEDG and prototype. This might be appropriate for compliance evaluations but it would not be appropriate for rating of commercial kitchens where high loads significantly impact the cooling and heating energy use. The prototype buildings approach was identified to be most appropriate and the tool models incorporate schedules of operation as identified by these buildings.

### 3.2. Identifying Typical Appliances and Refrigeration Equipment

The typical appliances in a commercial kitchen include refrigerators, freezers (Zhang et al. 2010), fryers, griddles, steamers, broilers, ovens, range top, and braising pans (Fisher Nickel 2002). We use the rated values from the 2013 ASHRAE Handbook of Fundamentals for the commonly found appliances in a commercial kitchen (ASHRAE 2013). Table 1 shows some common commercial kitchen appliances’ annual energy use operating under the tool’s standard operations.

**Table 1. Standard and Energy Efficient Appliances**

	Electric Appliances (MBtu/yr)		Gas Appliances (MBtu/yr)	
	Standard	Energy Efficient	Standard	Energy Efficient
Broiler	53	40	138	104
Freezer (Reach In)	15	11	N/A	N/A
Freezer (Undercounter)	10	9	N/A	N/A
Fryer	69	48	115	81
Griddle	84	76	130	117
Holding Cabinet	45	13	N/A	N/A
Ice Machine	45	39	N/A	N/A
Microwave	16	13	N/A	N/A
Oven (Convection)	59	51	80	68
Oven (Conveyor)	30	25	N/A	N/A
Refrigerator (Prep Table)	18	11	N/A	N/A
Refrigerator (Reach In)	42	25	N/A	N/A
Refrigerator (Undercounter)	4	3	N/A	N/A
Steam Kettle	159	143	209	167
Steamer (Bun)	7	4	N/A	N/A
Steamer	48	29	38	26

### 3.3. Identifying Air Requirements and Control

#### 3.3.1. Exhaust Requirements based on Appliance Duty Level

ASHRAE Standard 154 (ASHRAE 2016) has identified four rating categories based on the exhaust airflow required to capture, contain, and remove the cooking effluent and products of combustion under typical operating conditions. The following appliance duty classifications are used in this standard:

- Light: a cooking process requiring an exhaust airflow rate of less than 200 CFM/ft for capture, containment, and removal of the cooking effluent and products of combustion. Convection ovens, combination ovens steamers, small kettles (up to 400 °F) etc. are some of the appliances that require light duty exhaust hoods.
- Medium: a cooking process requiring an exhaust airflow rate of 200 to 300 CFM/ft. Conveyor ovens, large kettles, ranges, fryers (up to 400 °F), griddles, open burner ranges are a few of the appliances identified by ASHRAE Standard 154 to required medium duty exhaust hoods.
- Heavy: a cooking process requiring an exhaust airflow rate of 300 to 400 CFM/ft. Under fire broilers and wok ranges are identified to require heavy duty exhaust hoods.
- Extra-heavy: a cooking process requiring an exhaust airflow rate greater than 400 CFM/ft. Solid fuel (wood, charcoal, briquettes and mesquite) appliances are required to have extra-heavy duty exhaust hoods.

Most commonly found appliances in commercial kitchens fall under the category of medium duty exhaust hoods, which have been assumed for all kitchen applications evaluated by the tool.

#### 3.3.2. Style of Exhaust Hoods

The design exhaust airflow rate depends on several features including the style of the exhaust hood, the effectiveness of its design and its length. Several styles of exhaust hoods are available such as wall mounted canopy, single island, double island, backshelf, eyebrow etc. Each style is engineered in a different manner due to which the effectiveness varies across different styles (Fisher Nickel 2002). Generally, for the same thermal plume challenge through cooking, a single-island canopy would require more exhaust than a wall-mounted canopy, which would require more exhaust than a backshelf hood. The tool would give credit for a more efficient hood style and normalize for variations in rate of exhaust airflow due to type and number of appliances. An effective normalization approach would be able to credit a kitchen with backshelf exhaust hoods when compared to a kitchen with wall mounted canopy hoods even if the exhaust airflow and consequent energy use of the former kitchen is higher due to operations or number of meals cooked per day.

ASHRAE Standard 154 defines the minimum exhaust airflow for both listed and unlisted styles of hoods. Listed

hoods are the ones that have been tested against a recognized standard, such as Underwriters Laboratories (UL) Standard 710 (UL 2016), whereas the hoods constructed to the prescriptive requirements of the building code are called unlisted hoods. Generally, listed hoods can be operated at a lower exhaust rate than an unlisted hood of the comparable style and size over the same cook line. In accordance to ASHRAE Research Project 1202 (ASHRAE 2005), listed hoods are often 30% more efficient than unlisted hoods. Table 2 below provides the exhaust airflow per linear foot of hood length for both listed and unlisted hoods for the different hood styles.

**Table 2. Exhaust Airflow Rate per Linear Foot of Hood Length**

Exhaust Hood Type	ASHRAE 154-2016	90.1-2013
	Unlisted exhaust hoods (CFM/linear foot)	Listed exhaust hoods (CFM/linear foot)
Wall mounted canopy	300	210
Single Island	500	350
Eyebrow	250	175
Backshelf	300	210
Double Island	250	175

### 3.4. Demand Controlled Kitchen Ventilation

Demand Control Kitchen Ventilation (DCKV) systems control ventilation by modulating the speed of the exhaust fans based on cooking activity. Schedules and ventilation requirements for DKCV met requirements put forth by Nonresidential Alternative Compliance Method Manual (NACM) 2013 guidelines (CASE 2013). NACM-2013 requires a standard DCKV enabled exhaust hood to be modeling using two fans. One fan runs 75% of the design exhaust volume and is controlled. The NACM-2013 fractional schedule for DCKV systems dictates the demand controlled fan’s operating conditions and hours. The second fan exhausts 25% of the design exhaust air at constant speed running during the same operating hours as the DCKV controlled fan.

## 4. NORMALIZATION APPROACH

The research carried out on appliances used in commercial kitchens shows a high variation in type and number of appliances. These are highly dependent on the kinds of food cooked. The type of appliance and the cooking effluent determines the exhaust hood duty (light, medium, heavy or extra heavy) that is required to be used for effective capture and containment (C&C) (Fisher Nickel 2002). Hence the exhaust airflow and the corresponding ventilation loads are also dependent on the type and number of appliances used.

### 4.1. Normalization Parameters

The normalization approach addresses the following variations observed in commercial kitchens:

- **Type of appliances:** An effective normalization approach would enable comparison of kitchens with varying types of appliances. For instance, a pizza restaurant with deck ovens should be comparable to a fast food restaurant with griddles and fryers. This is achieved by developing a baseline kitchen that includes all appliances that would be present in both kitchens.
- **Quantity of Appliances:** A kitchen serving more meals per day may be equipped with more appliances compared to a kitchen serving fewer meals per day. The normalization approach credits a higher number of energy efficient appliances and therefore does not penalize restaurants that need more kitchen equipment.
- **Kitchen Area:** The tool scores a building on its energy use intensity (EUI) which is normalized by floor area. Appliances are rated by their input power consumption (W) which does not account for variations in kitchen size. Hence, two kitchens with the same assets but varying floor area would score differently as the same energy use would be normalized over different areas. The proposed normalization approach accounts for this variation through the baseline kitchen which is always assumed to be 100 W/ft<sup>2</sup> and is adjusted according to the appliances present in the

kitchen being evaluated.

- **Exhaust Air:** The desired normalization approach would give credit to efficient hood style and would normalize for variations in volume of exhaust airflow. Exhaust hoods are rated by exhaust airflow per linear foot of hood length. Hence, in our proposed normalization we adjust the total length of exhaust hood in feet over the total square feet of the kitchen area. This normalizes for exhaust airflow and kitchen area at the same time, while giving credit to the hood style.

The rating approach should give credit to the following building assets:

- **Appliance Energy Efficiency:** Appliance energy efficiency is a measure of how much of the energy that an appliance consumes is actually delivered to the food product (Fisher Nickel 2002). There are several technologies that can improve the performance and energy efficiency of good service equipment, including improved heat exchanger design, enhanced control, thermostatic controls, power burners etc. The asset rating methodology should recognize appliances with advanced controls and give credit for the use of energy efficient technologies.

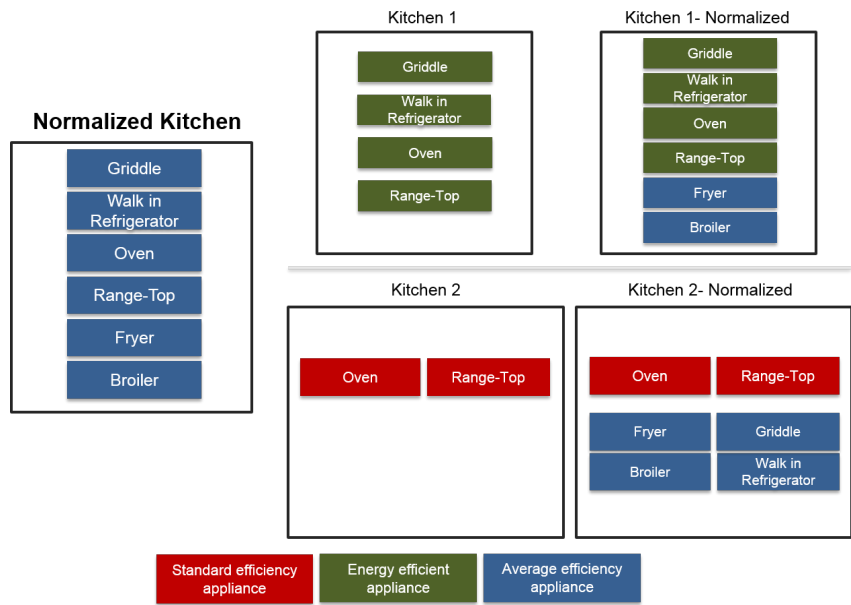
- **Gas vs Electric Appliances:** Electric appliances are more efficient than gas appliances partly due to higher effectiveness of the heat exchanger for electric appliances. On average, a gas fryer or griddle can consume twice as much energy at full load conditions (Fisher Nickel 2002). The tool uses source energy for scoring buildings due to which gas appliances, though less efficient than electric appliances, are bound to score higher due to the lower site-to-source conversion ratios. The normalization approach addresses this issue by accounting for both gas and electric appliances in the normalized baseline hence crediting a kitchen for the use of efficient electric appliances.

## **4.2. Normalized Baseline Model**

The normalization approach developed for scoring commercial kitchens normalizes for type of appliances, number of appliances, kitchen area and exhaust airflow, and gives credit to energy efficient appliances, exhaust hood style, and exhaust hood listing.

### **4.2.1. Normalizing for Type of Appliances**

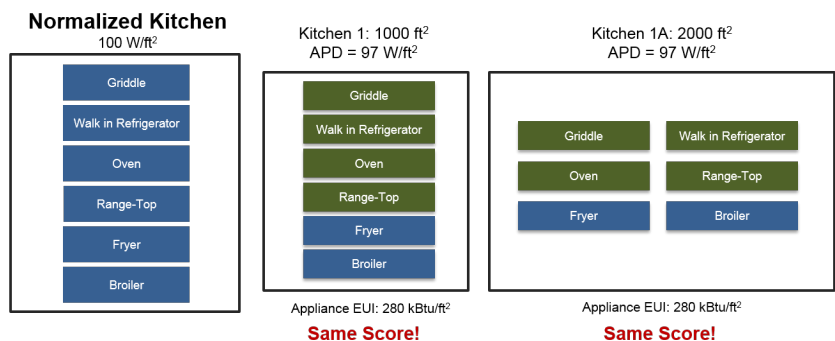
This is achieved by developing a baseline kitchen model that has one of each kind of appliance and refrigeration equipment being evaluated by the tool, at an “average efficiency.” In Section 3.2 we presented the annual energy consumption for standard and energy efficient appliances and refrigeration equipment. Average efficiency, for the purpose of the tool, is defined as the average input power rating of a standard and energy efficient appliance. Hence, the normalized baseline kitchen is assumed to have one of each appliance type at average efficiency and is then modified to reflect the kitchen being evaluated, as illustrated in Figure 2.



**Figure 2** Simplified example of appliance type normalization with only 6 appliances. The tool’s calculation uses 24 different appliance types.

#### 4.2.2 Normalizing for Kitchen Area

Appliances are typically defined with an input power rating (W) and not a W/ft<sup>2</sup>. Without normalization, a smaller kitchen will score lower than a larger kitchen, with all other attributes being the same. To normalize for kitchen area, an appliance power density (APD) of 100 W/ft<sup>2</sup> is assumed (based on the Full-Service Restaurant prototype, DOE 2017), which is then adjusted based on the appliances present in the kitchen being evaluated. For instance, if the evaluated kitchen has four energy efficient appliances, the savings of these four appliances over the average efficiency appliances would be calculated and the baseline APD would be adjusted to account for these savings. In the example highlighted in Figure 3, two kitchens with same assets but varying floor area are considered. Using the methodology described, both kitchens would be modeled with the same appliance power density, resulting in similar EUIs and same asset scores.



**Figure 3** Normalization for kitchen area.

#### 4.2.3. Normalizing for Number of Appliances

In addition to appliance type, the normalized baseline kitchen model takes into consideration multiple of the same appliances. Since the tool evaluates assets, kitchens with multiples of the same energy efficient appliance score higher. Conversely, the same kitchen, but with fewer energy efficient appliances, receives a lower score. To accomplish this, the baseline kitchen model is modified to include the additional appliances. Consider Kitchen 1 from Figure 3 but with an additional energy efficient oven. Kitchen 1B in Figure 4 reflects the modification. The new baseline includes two average ovens instead of one. The modification happens only when multiple of the same appliances are evaluated. For all other appliance types, the baseline kitchen model still has one average efficiency appliance. As a result, making the oven's energy a larger portion of the kitchen's appliance energy use allows for kitchens with a greater number of energy efficient ovens to score better than kitchens with a single energy efficient oven.

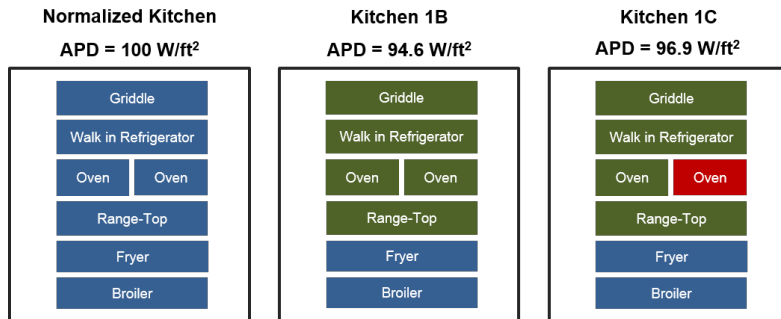


Figure 4 Normalization for number of appliances.

### 4.3. Evaluation Scenario

In this section, we present the overall methodology. For example, Kitchen 1 represents a 1000 ft<sup>2</sup> space with four appliances and an annual EUI of 650 kBtu/ft<sup>2</sup>. In addition, Kitchen 2 represents a 2000 ft<sup>2</sup> space equipped with two appliances and an annual EUI of 400 kBtu/ft<sup>2</sup>. Based on EUI, Kitchen 2 would appear to be more energy efficient than Kitchen 1. However when compared using the normalization approach implemented in the tool, Kitchen 2 scores lower than Kitchen 1. In Figure 5, the tool's methodology shows the normalized version of both kitchens adjusted to reflect the efficiency levels of appliances present in the kitchen. This enables the comparison of multiple configurations and rates the kitchen assets irrespective of actual operation.

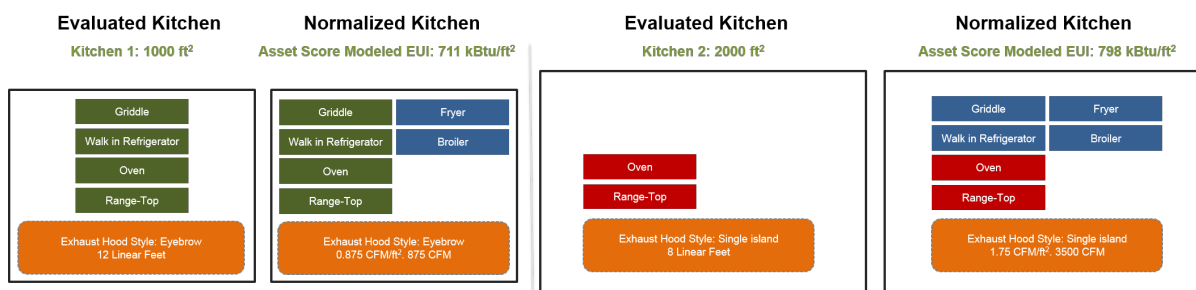


Figure 5 Overall methodology.

## 5. CONCLUSION

The tool's evaluation methodology standardizes kitchen configurations allowing for comparison and analysis of Food Service building use types. We identify the energy use drivers in commercial kitchens and propose a methodology to evaluate their energy efficiency. The methodology presented in this paper demonstrates techniques to normalize for variations in appliance type, efficiency, and amount, and ventilation and exhaust requirements. The methodology provides a technically robust approach to fairly score different Food Service buildings.



## REFERENCES

- ANSI/ASHRAE Standard 154-2011. 2016. Ventilation for Commercial Cooking Operations.
- ASHRAE. 2013. ASHRAE Handbook: Fundamentals. Atlanta, GA.
- ASHRAE. 2015. RP-1202 -- Effect of Appliance Diversity and Position on Commercial Kitchen Hood Performance.
- CASE (Codes and Standards Enhancement Initiative). Kitchen Ventilation. 2013. California Building Energy Efficiency Standards. Available: [http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Nonresidential/Covered\\_Processes/2013\\_CASE\\_ASHRAE5-KitchenVent\\_09.30.2011.pdf](http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Nonresidential/Covered_Processes/2013_CASE_ASHRAE5-KitchenVent_09.30.2011.pdf) [Accessed 1 December 2017].
- Crawley, D., Pedersen, C., Lawrie, L., and Winkelmann, F. 2000. EnergyPlus: Energy Simulation Program. ASHRAE Journal, 42 (4), 49.
- DOE. 2017. Commercial Prototype Building Models. Available: [https://www.energycodes.gov/development/commercial/prototype\\_models](https://www.energycodes.gov/development/commercial/prototype_models) [Accessed 1 December 2017].
- EnergyStar. 2017. *ENERGY STAR for Small Business: Restaurants*. Available online: <https://www.energystar.gov/buildings/facility-owners-and-managers/small-biz/restaurants> [Accessed 30 November 2017].
- EnergyPlus. 2017b. Available: <https://energyplus.net/> [Accessed 1 December 2017].
- EIA. 2017. Commercial Buildings Energy Consumption Survey (CBECS), Table E2. Major fuel consumption intensities (Btu) by end use, 2012. Available: <https://www.eia.gov/consumption/commercial/data/2012/c&e/cfm/e2.php> [Accessed 4 December 2017].
- Fisher Nickel INC. 2002. Commercial Cooking Appliance Technology Assessment. Available: [https://fishnick.com/equipment/techassessment/Appliance\\_Tech\\_Assessment.pdf](https://fishnick.com/equipment/techassessment/Appliance_Tech_Assessment.pdf) [Accessed 1 December 2017].
- OpenStudio. 2017. Available: <https://www.openstudio.net/developers> [Accessed 1 December 2017].
- Thornton BA, M Rosenberg, EE Richman, W Wang, Y Xie, J Zhang, H Cho, VV Mendon, RA Athalye, and B Liu. 2011. Achieving the 30% Goal: Energy and Cost Savings Analysis of ASHRAE Standard 90.1-2010. PNNL-20405, Pacific Northwest National Laboratory, Richland, Washington.
- Underwriters Laboratories (UL) Standard 710. 2016. Standard for Safety: Exhaust hoods for Commercial Cooking Equipment.
- Wang, N., Makhmalbaf, A., Srivastava, V., and Hathaway, J.E. 2017. Simulation-based coefficients for adjusting climate impact on energy consumption of commercial buildings 10(3): 309-322. <https://doi.org/10.1007/s12273-016-0332-1>
- Wang, N., Goel, S., Makhmalbaf, A., and N. Long, 2016. Development of building energy asset rating using stock modelling in the USA. Journal of Building performance Simulation 1-15. <https://doi.org/10.1080/19401493.2015.1134668>
- Wang, N., Goel, S., Srivastava, V., and Makhmalbaf, A. 2016. Building Energy Asset Score Program Overview and Technical Protocol (Version 1.2). PNNL-22045 Rev. 1.2. Available: [https://buildingenergyscore.energy.gov/documents/energy\\_asset\\_score\\_technical\\_protocol.pdf](https://buildingenergyscore.energy.gov/documents/energy_asset_score_technical_protocol.pdf) [Accessed 1 December 2017].
- Zhang, J., Schrock, D.W., Fisher, D.R., Livchak, A., Zabrowski, D.A., Lane, M.D., Athalye, R.A., and Liu, B. 2010. Technical Support Document: 50% Energy Savings for Quick-Service Restaurants. Available: [https://www.pnnl.gov/main/publications/external/technical\\_reports/PNNL-19809.pdf](https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-19809.pdf) [Accessed 1 December 2017].