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Defining the Prototype Convenience Store Building Characteristics

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OAK RIDGE National Laboratory

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Buildings and Transportation Science Division

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ABSTRACT

The US Department of Energy supports the development of commercial building energy codes and standards. To support commercial building energy research activities and the development of commercial building energy codes and standards, continuous efforts have been made to convert 30 prototype building models (20 different building types), which cover 80% of US commercial building floor space, to OpenStudio prototype buildings. Additionally, the suite of prototype building models was expanded to include the addition of new building prototype models (e.g., courthouse, college building). This report documents the building and system characteristics of the prototype convenience store building model.

Multiple sources, including databases, documented projects, and personal communications, were used to define the prototype convenience store building characteristics, and a one-story, 3,000 ft^2 building was considered as the prototype convenience store to represent an average-sized convenience store in the United States. The Oak Ridge National Laboratory team defined the operational hours of the convenience store as 17 hours per day. The types of exterior walls, roof, and floor were defined as brick wall, metal surfacing roof, and slab-on-grade floor, respectively. Double glazing was selected, and the window-to-wall ratio was set as 15% on the front side. For the system part, packaged system and centralized water heater were selected for the space heating and cooling system and water heater system, respectively. In terms of the refrigerator system, the number of refrigerators and freezers were determined as eight closed cases and two walk-in units.

1. INTRODUCTION

1.1 BACKGROUND

The US Department of Energy supports the development of commercial building energy codes and standards. To support commercial building energy research activities and the development of commercial building energy codes and standards, continuous efforts have been made to convert 30 prototype building models (20 different building types), which cover 80% of US commercial building floor space, to OpenStudio prototype buildings (USDOE 2022). Additionally, the suite of prototype building models was expanded to include the addition of new building prototype models (e.g., courthouse and college building).

To determine the building types and prioritize the model development for this suite, Commercial Buildings Energy Consumption Survey (CBECS) building type subcategories and relevant survey data were used. For the selected building types, building and system characteristics were researched using a variety of resources to develop building descriptions, thermal zone internal loads, schedules, and other key modeling input information necessary to create a canonical building energy model (Deru et al. 2011).

"Convenience store (with or without a gas station)" is a building type subcategory under the CBECS "Food Sales" building category that refers to all buildings used for retail or wholesale of food. Other subcategories under Food Sales include grocery store or food market and bakery (EIA 2022a).

CBECS classifies commercial buildings into 12 major building types, which are education, food sales, food service, health care, lodging, mercantile, office, public assembly, public order and safety, worship, service, warehouse, and storage. Under the 12 major building types, 46 building types are classified.

The OpenStudio Standard prototype building models already covers 31 building types. Of the 15 building types that are not covered by the existing OpenStudio Standard prototype building models, the convenience store has the largest energy use intensity (EUI), which is energy consumption per floor area. The EUI for a convenience store is 684.6 kWh/m^2 (216.3 kBtu/ft^2), which is 2.7 times larger than the EUI for a commercial building (252.2 kWh/m^2 [80 kBtu/ft^2]). Out of the 15 remaining building types that are not covered by the existing OpenStudio Standard prototype building model, the convenience store ranks fifth in the largest number of stores. Because the number of convenience stores is 10% of the total number of 15 remaining building types and consumes the largest energy per floor area, the OpenStudio Standard prototype building model needs to be developed.

This study used multiple resources to define the OpenStudio prototype convenience store building model and presents the research conducted to define both building and system characteristics.

1.2 CONVENIENCE STORE BUILDING VERSUS OTHER BUILDINGS IN CBECS

To gauge the share of the convenience store building type in existing US buildings and the energy used in the buildings, the 2012 and 2018 CBECS data (EIA 2016) for convenience store buildings was compared with other building types included in the suite of commercial prototype building models (Building Energy Codes Program 2016).

1.2.1 Percentage of Total Commercial Building Floor Space

The 2012 and 2018 CBECS data represent 131,000 and 120,688 convenience store buildings in the United States, respectively. As shown in Figure 1, convenience store buildings occupy a total of 470

million ft^2 of floor space, or 0.5% of the US commercial floor space. In terms of the number of buildings, convenience store buildings account for 2.4% of the number of US commercial buildings.

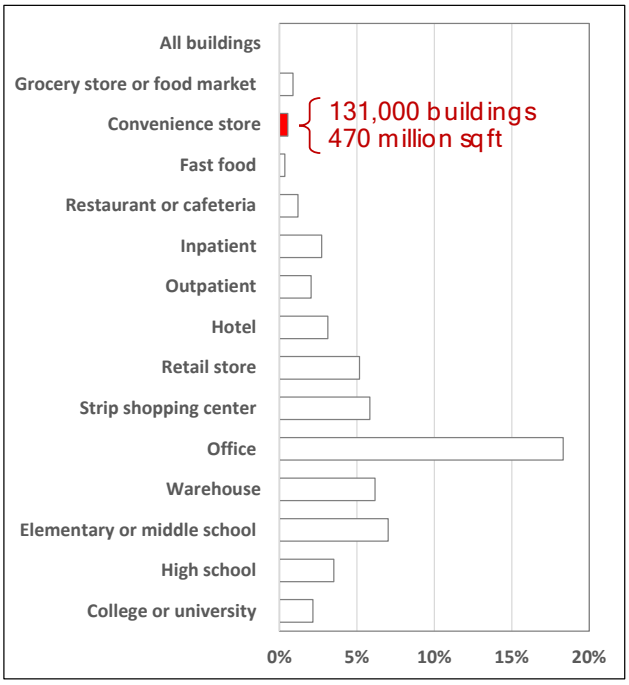


Figure 1. Percentage of total building floor space for convenience store buildings compared with other buildings currently in the suite of commercial prototype building models. Source: EIA 2015.

1.2.2 Fuel Consumption Intensity

Convenience store buildings contribute 1.5% of the total fuel consumption in US commercial buildings. Figure 2 plots the fuel consumption intensity against mean floor area of convenience store building and other buildings. The clusters indicate building types that are similar in terms of average size and energy use. Fuel consumption intensity for the convenience store is 216.3 kBtu/ft^2, which is 2.7 times larger than the EUI for commercial buildings (80 kBtu/ft^2) (EIA 2016).

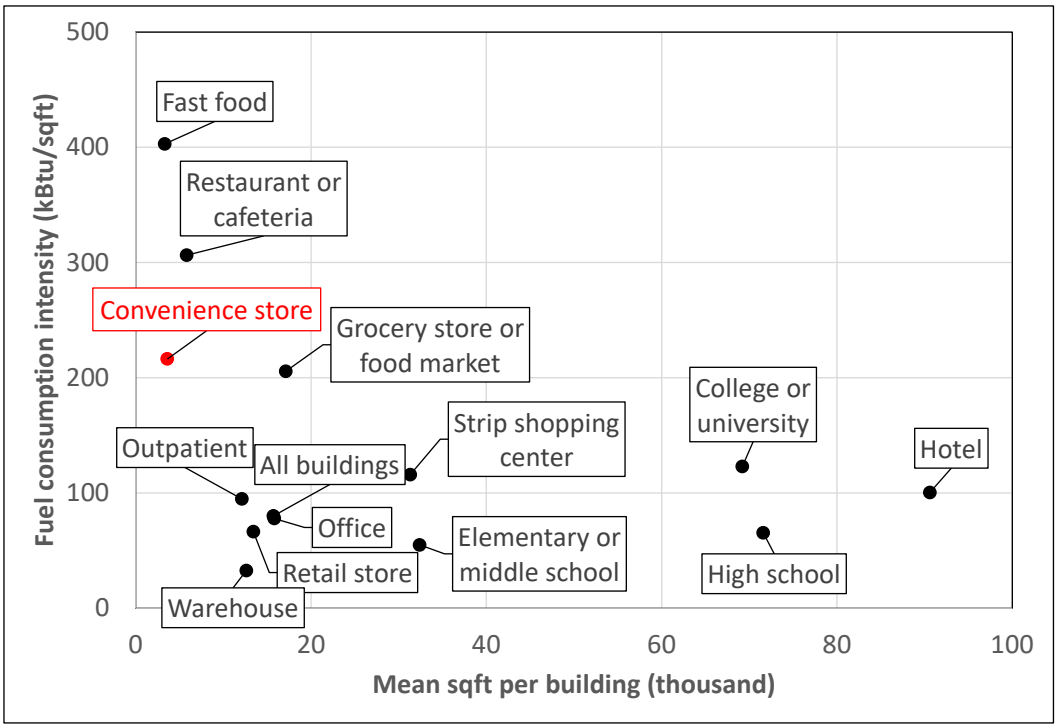


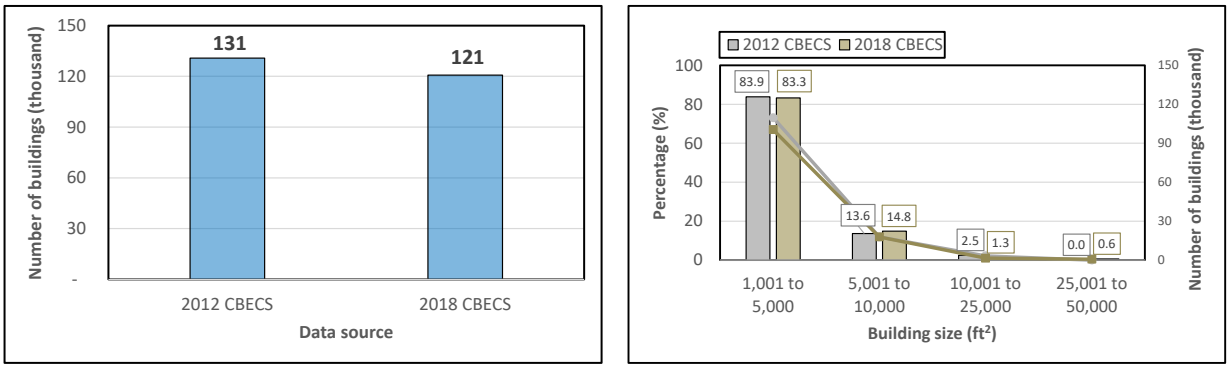
Figure 2. Fuel consumption intensity plotted against mean floor area for convenience store buildings and other buildings. Source: EIA 2015.

2. REVIEW OF THE EXISTING RESOURCES OF THE CONVENIENCE STORE BUILDING

To define the convenience store prototype model, typical characteristics of the convenience store need to be defined, including building size, aspect ratio, floor plan, type of construction, glazing type, type of heating and cooling systems, and type of refrigeration systems. The Oak Ridge National Laboratory (ORNL) team reviewed the 1992, 2012, and 2018 CBECS data, for their respective merits, to define the characteristics of convenience store buildings. The 2012 CBECS dataset includes separate subcategories for convenience stores with and without gas stations; in the 1992 and 2018 CBECS datasets, these subcategories are combined. The 1992 CBECS dataset provides building shape, length, and width; in the 2012 and 2018 CBECS datasets, these details are not provided. The typical floor plan of convenience stores is determined based on review of design guides, codes and regulations, and floor plans of existing and sample convenience stores.

2.1 BUILDING CHARACTERISTICS

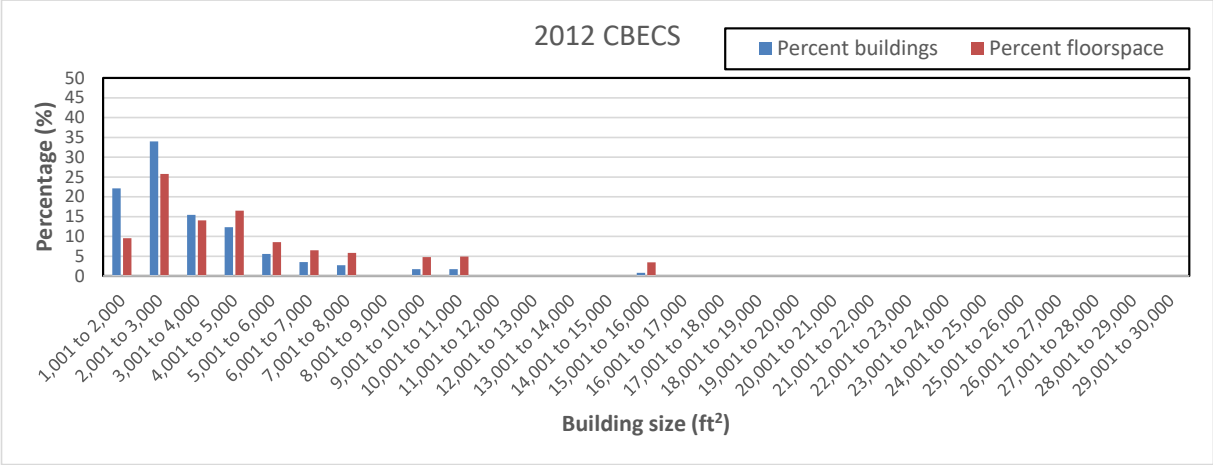
Figure 3 shows the number and floor area of convenience store buildings. The 2012 and 2018 CBECS datasets were generated based on the more than 130,000 and 120,000 existing convenience store buildings, respectively. More than 83% of convenience store buildings in the 2012 and 2018 CBECS datasets have a floor area between 1,001 and 5,000 ft^2. Only 13%–15% of convenience stores have a floor area between 5,001 and 10,000 ft^2. Convenience store buildings with floor space larger than 10,001 ft^2 account for less than 3% of the total. According to the 2012 CBECS dataset, which has separate categories for convenience stores with and without gas stations, the average and median floor areas are 3,643 ft^2 and 3,041 ft^2 for convenience store with gas stations; 3,570 ft^2 and 2,986 ft^2 for convenience stores without gas stations; and 3,599 ft^2 and 3,000 ft^2 for convenience stores combining these categories (EIA 2015). Interestingly, in the 2018 CBECS dataset, the average and median floor areas for convenience stores are 3,353 ft^2 and 2,100 ft^2 (EIA 2022b), respectively.



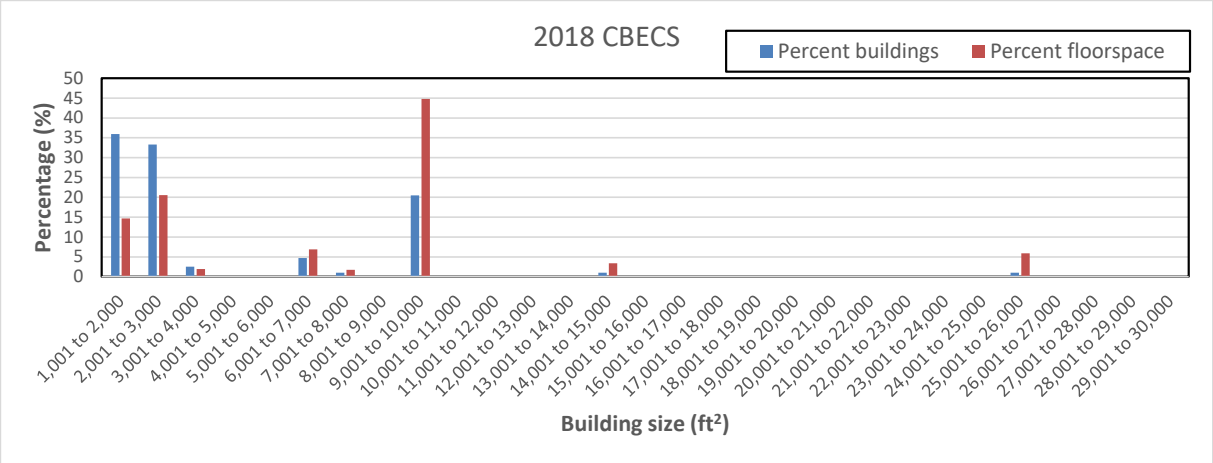
(a) Number of convenience store buildings (b) Floor area of convenience store buildings

Figure 3. Number and floor area of convenience store buildings. Source: EIA 2015 and EIA 2022b.

The much larger difference between the average and median floor areas in the 2018 CBECS dataset compared with the 2012 CBECS dataset deemed closer review of the area distribution. Figure 4 shows the percent distribution by number of buildings (blue bars) and percent distribution by floorspace (red bars) for convenience stores based on the 2012 CBECS (Figure 4 (a)) and 2018 CBECS (Figure 4 (b)) datasets. The 2012 CBECS dataset shows a smoother distribution compared with the 2018 CBECS dataset. Therefore, we selected the 2012 CBECS dataset as a better source for determining floor area. We set 3,000 ft^2 as a floor area of the prototype convenience building model based on the median floor area from the 2012 CBECS dataset.



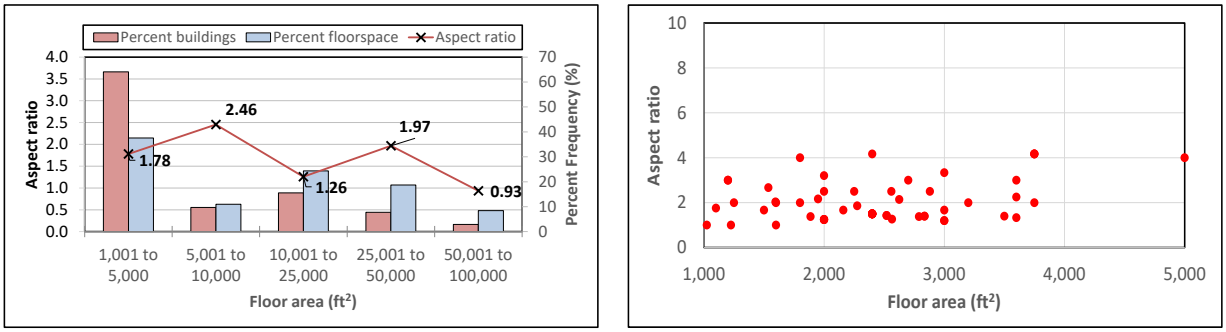
(a) Percent distribution of convenience store buildings by number of buildings and floor space in 2012 CBECS dataset



(b) Percent distribution of convenience store buildings by number of buildings and floor space in 2018 CBECS dataset

Figure 4. Percent distribution of convenience store buildings by number of buildings and floorspace. Source: EIA 2015 and EIA 2022b.

Using the information on building length and width that the 1992 CBECS dataset provided, the ORNL team calculated the aspect ratio. Figure 5 (a) shows the typical aspect ratio of the convenience store buildings depending on the floor area; and Figure 5 (b) shows the aspect ratio of the convenience store buildings with a floor area of 1,001 to 5,000 ft^2, which is a typical floor area of the convenience store buildings, as shown in Figure 3. The aspect ratio of the most convenience store buildings with a floor area of 1,001 to 5,000 ft^2 is between 1 to 2, and the averaged aspect ratio of convenience store buildings with a floor area of 1,001 to 5,000 ft^2 is 1.78. The ORNL team set 1.5 as the aspect ratio of the prototype convenience building model based on the review of the 1992 CBECS dataset.



(a) Typical aspect ratio of convenience store buildings

(b) Aspect ratio of convenience store buildings with a floor area of 1,001 to 5,000 ft²

Figure 5. Aspect ratio of convenience store buildings. Source: EIA 1996.

Figure 6 shows the operational hours of convenience store buildings. In both the 2012 and 2018 CBECS datasets, more than 65% of convenience stores operate more than 16 hours per day. The longer operational hours of convenience stores versus those of typical commercial buildings is one of the reasons why convenience store buildings have larger EUI than that of the typical commercial buildings.

Even though more than 25% of convenience stores operate 24 hours per day, another 40% of convenience stores operate 16 to 23 hours per day. Because the prototype model needs to represent typical characteristics of the building, the ORNL team calculated average operational hours and median operational hours to define the typical operational hours of the convenience store building. The average and median operational hours in the 2012 CBECS dataset are 127.1 hours and 119 hours, respectively (EIA 2015). In the 2018 CBECS dataset, the average operational hours and median operational hours are 117.7 and 112 hours, respectively (EIA 2022b). Based on the analysis, the ORNL team set 119 hours (17 hours per day) as the building operational hours for the prototype convenience store building model.

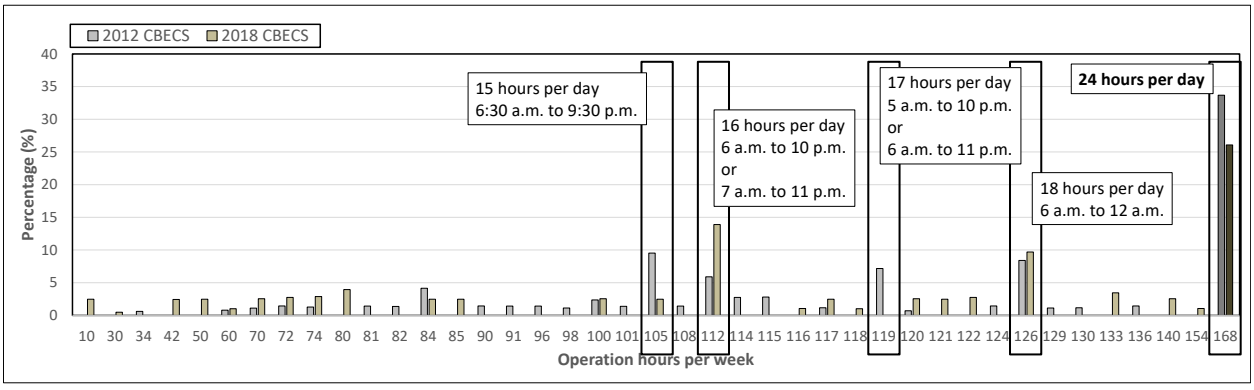
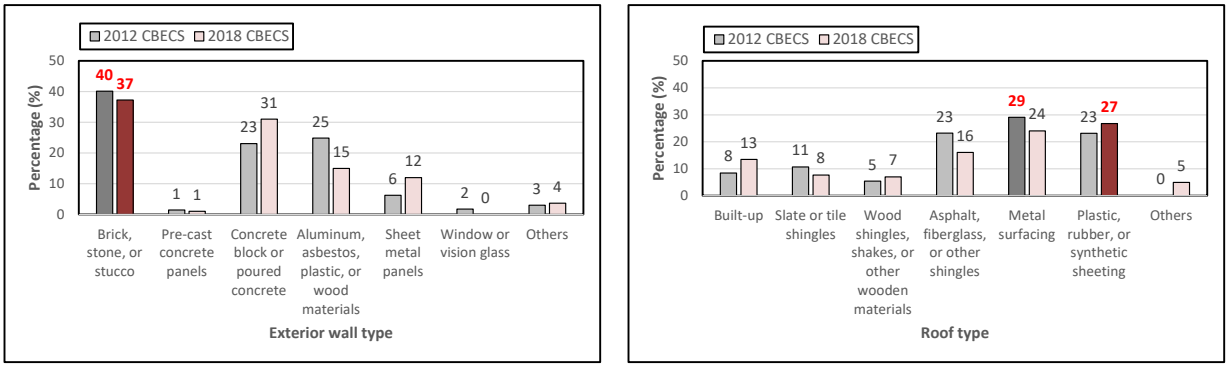


Figure 6. Operational hours of convenience store buildings. Source: EIA 2015 and EIA 2022b.

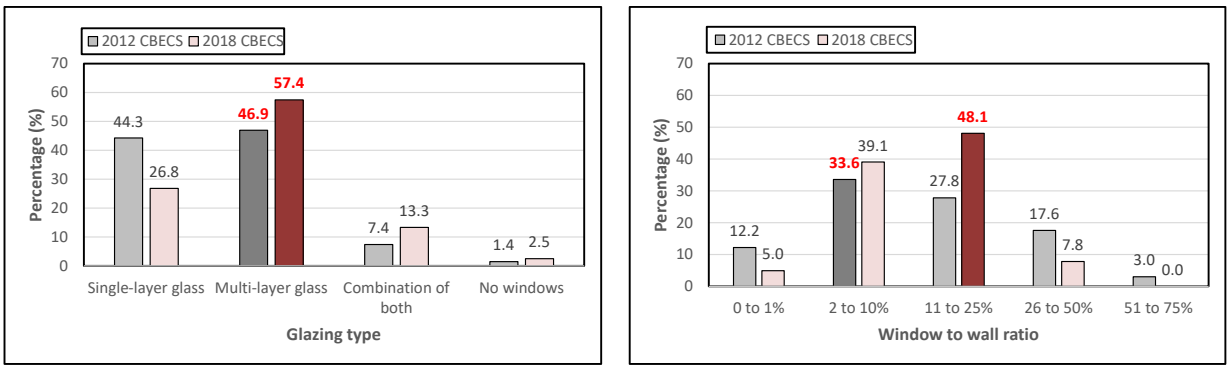
Figure 7 shows the type of the exterior wall and exterior roof of the convenience stores. About 40% of convenience stores have brick, stone, or stucco-based exterior walls, and about 20% to 30% of convenience stores have concrete block or poured concrete-based exterior walls. In terms of the exterior roof, the typical roof type is different depending on the version of the CBECS dataset. In the 2012 CBECS dataset, the typical roof type is metal surfacing based; in the 2018 CBECS dataset, the typical roof type is plastic, rubber, or synthetic sheeting based. The ORNL team set brick type and metal surfacing type as types of exterior wall and exterior roof for the prototype convenience store building model.



(a) Type of exterior wall (b) Type of exterior roof

Figure 7. Type of exterior wall and exterior roof of convenience store buildings. Source: EIA 2015 and EIA 2022b.

Figure 8 shows the glazing type and window-to-wall ratio of the convenience stores. About 50% of convenience stores have multi-layer glazing, which means double glazing or triple glazing. The typical window-to-wall ratio is different depending on the version of the CBECS dataset. In the 2012 CBECS dataset, 2% to 10% is the typical window-to-wall ratio; in the 2018 CBECS dataset, 11% to 25% is the typical window-to-wall ratio. When we considered both the 2012 and 2018 CBECS datasets, 11% to 25% is the typical window-to-wall ratio of convenience stores. Since multi-layer glass is a common glazing type, the ORNL team selected double glazing as the glazing type and set 15% as the window-to-wall ratio for the prototype convenience store building model.



(a) Type of glazing (b) Window-to-wall ratio

Figure 8. Type of glazing and window-to-wall ratio of convenience store buildings. Source: EIA 2015 and EIA 2022b.

2.2 FLOOR PLAN OF THE CONVENIENCE STORE

Characteristics of convenience stores in the United States vary widely in terms of activity/functions housed in the facility (e.g., gas stations, car washes, food service), location (near highways or in residential or commercial areas), operational hours (extended, 24/7, or otherwise), and size (NACS 2022). Before researching the building and system characteristics for convenience stores, it is important to recognize these variations and statistics (if available). This information can be used to prioritize and define a narrative for the prototype model to represent most, if not all, types of convenience stores and is important for accurately defining the space types and hours of operation.

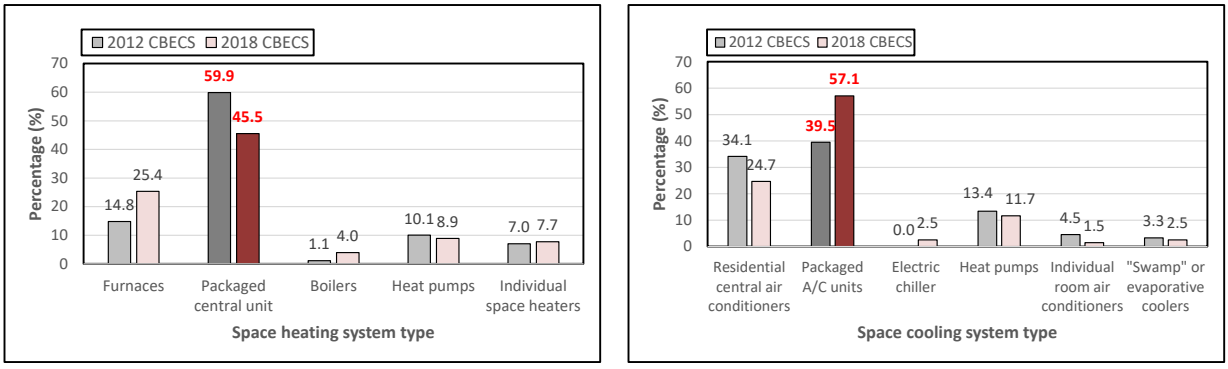
According to a report by NielsonIQ and the Association for Convenience & Fuel Retailing (NACS/NielsenIQ 2022), there are 148,026 convenience stores in the United States, of which ~80% sell fuel. Other fueling locations include gas-only stations, grocery stores, service stations, marinas, and so on. The number of convenience stores with gas stations has decreased over the years as demand has plateaued and drivers seek out modern stations with more fueling spots and/or a robust in-store offerings. Approximately 95% of branded fuel stations (including convenience stores) are owned and operated by independent retailers licensed to represent that brand. Thus, the characteristics of convenience stores with and without gas stations are similar. The design and layout of convenience stores with gas stations is not guided by any fuel brand.

In the 2012 CBECS dataset, convenience stores without and with gas stations are listed under separate categories. In the 2018 CBECS dataset, convenience stores without and with gas stations are combined into one category.

To define the typical floor plan of the convenience store, design guides, codes and regulations, and floor plans of existing and sample convenience stores were reviewed. Generic design guides, as well as local jurisdiction regulations, are readily available for gas stations. With the primary focus on safety and compliance with codes and regulations, guidance is provided on fuel kiosk design, canopy height, exterior lighting requirements, clearance, parking, underground fuel station location, access and circulation, and so on (Stanton and Friedman 2016; Manross et al. 1999; WBDG 2022; Architecture4Design 2022; Dutchess County Government 2013; TACHYON 2020; SeaTac Municipal Code 2022). Guidance on the floor plan and location/placement of merchandise and refrigeration units inside the convenience store building is mainly noted from sample plans and resources by NACS (NACS 2022).

2.3 HVAC AND WATER HEATER SYSTEM CHARACTERISTICS

This chapter describes the typical heating and cooling system and water heater system. Figure 9 shows the type of the space heating and cooling system of convenience store buildings. In both the 2012 and 2018 CBECS datasets, packaged central units are the typical space heating system of convenience store buildings. Packaged central unit systems are installed for space heating in ~50% of convenience store buildings. For space cooling, packaged air conditioning units are the typical space cooling system for convenience store buildings in both the 2012 and 2018 CBECS datasets. Consequently, the ORNL team selected packaged central unit and packaged air conditioning unit for the space heating and cooling system for the prototype convenience store building model.



(a) Type of space heating system (b) Type of space cooling system

Figure 9. Type of heating and cooling systems of convenience store buildings. Source: EIA 2015 and EIA 2022b.

Figure 10 shows the type of water heater system for convenience store buildings. Centralized water heater systems are installed in more than 70% of convenience stores in both the 2012 and 2018 CBECS datasets. In the 2018 CBECS dataset, convenience store buildings with point-of-use water heaters have increased by three times compared with the 2012 CBECS dataset, but centralized water heater systems are still installed in 70% of convenience store buildings. The ORNL team selected a centralized water heater system as the type of water heater system for the prototype convenience store building model based on review of the 2012 and 2018 CBECS datasets.

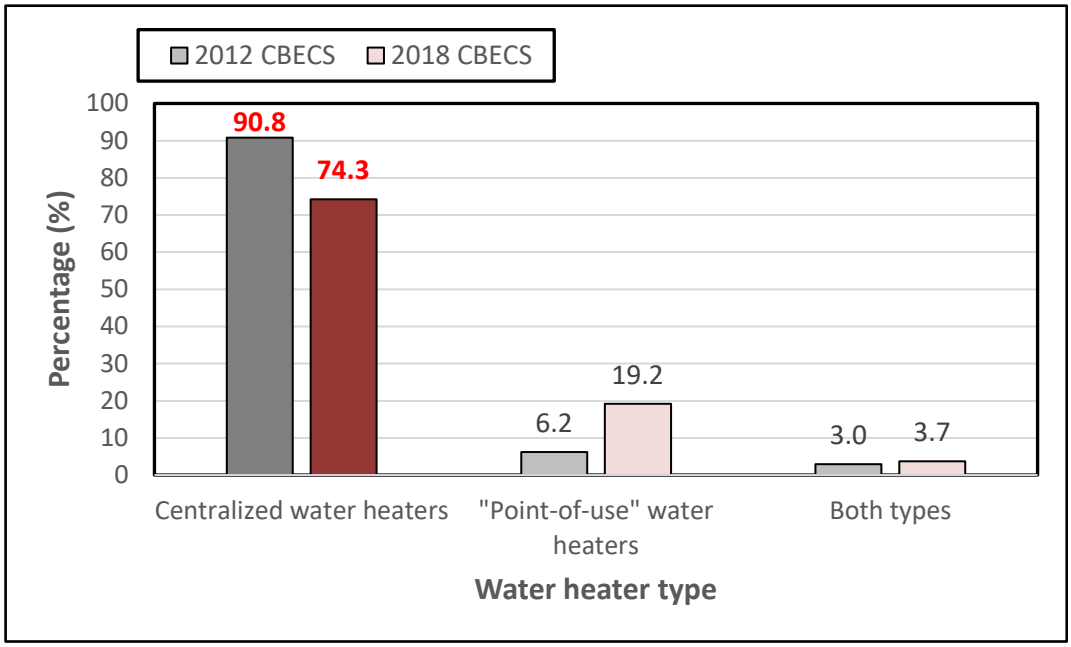


Figure 10. Type of water heater systems for convenience store buildings. Source: EIA 2015 and EIA 2022b.

2.4 REFRIGERATION SYSTEM CHARACTERISTICS

As described previously, convenience store buildings have a larger EUI than that of other commercial buildings mainly because of extended building operation hours and the refrigeration systems. As shown in Figure 6, more than 65% of the existing convenience store buildings operate more than 16 hours per day. Compared with other typical prototype model buildings, the building operation hours are longer for convenience stores, which directly affects increased building heating, ventilation, and air conditioning (HVAC) energy consumption. The other reason for larger EUI is the refrigeration systems used. In grocery stores that have similar systems but larger-scale of the systems, almost half of the total energy is consumed by refrigeration systems, and the compressors are the main component that consumes significant energy within the refrigeration systems. Convenience stores also have refrigeration systems to sell cold or frozen food. Because such refrigerators and freezers are fully operated for 24 hours, even when the convenience store is closed, the energy use of the refrigeration system is also significant.

In addition, refrigeration systems in convenience stores interact with the HVAC systems, especially when the doors of refrigerated cases are opened. The opened doors provide uncontrolled cooling to the sales area, requiring heat to maintain the setpoint temperature and occupant comfort. Compared with grocery stores, since most refrigerated cases are closed cases in convenience stores, the effect of this interaction is minimized and the total load on refrigeration is reduced. However, it is still important to capture this effect by identifying accurate schedules of door openings, and this information needs to be considered in developing the prototype convenience store energy model.

To define the refrigeration system characteristics, the ORNL team reviewed the CBECS data to understand how many refrigerators are installed in convenience store buildings. Figure 11 shows the number of refrigerators in convenience store buildings. Typically, five to seven refrigerators are installed in convenience store buildings smaller than 10,000 ft^2. In terms of vending machines and ice makers, one out of two or three convenience store buildings is typically equipped with a vending machine and an ice maker.

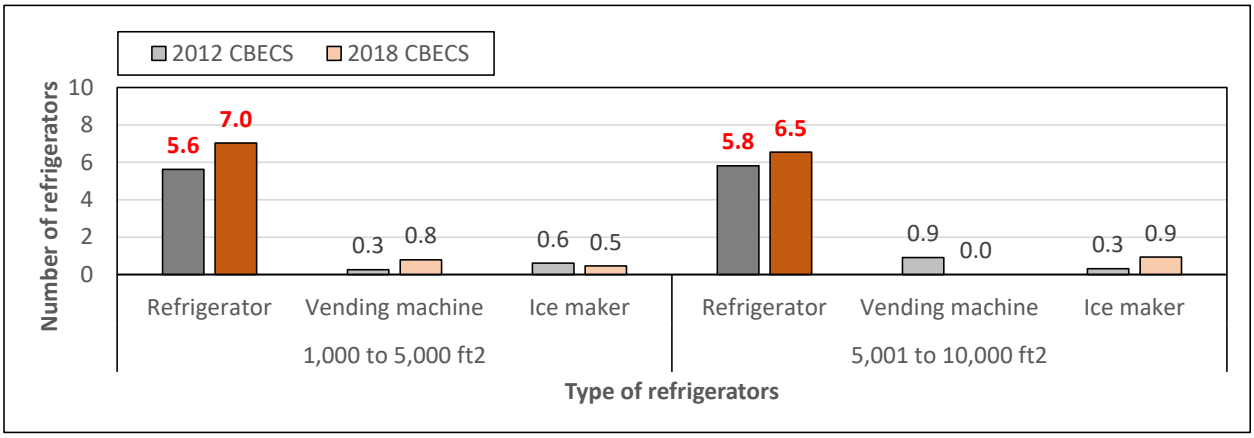


Figure 11. Number of refrigerators in convenience store buildings. Source: EIA 2015 and EIA 2022b.

3. DEFINING CHARACTERISTICS OF THE CONVENIENCE STORE BUILDING

Through the systematic approach, the ORNL team defined the characteristics of the convenience store building to develop the prototype convenience store building model in the near future.

3.1 BUILDING SIZE AND CONSTRUCTION TYPE

This section defines the building characteristics used to develop the prototype convenience store building model. Table 1 and Table 2 show the geometry of the prototype convenience building model. The prototype convenience store building is a single-story building with a floor area of 3,000 ft^2. The floor-to-ceiling height is 10 ft, and the plenum height is 3 ft. The window-to-wall ratio is 15% on the front side.

Table 1. Size of the prototype convenience store building model.

Parameter	Value
Total floor area	3,000 ft^2 (77.5 × 38.75 ft)
Aspect ratio	1.5
Number of floors	1
Floor-to-ceiling height	10 ft
Plenum height	3 ft
Window-to-wall ratio	15% (front)

As described in Section 2, the exterior wall type is a brick, and the roof type is a metal surfacing roof. Because multi-layer glazing is common for convenience stores, the ORNL team selected double-glazing for the prototype convenience store building model.

Table 2. Construction type of the prototype convenience store building model.

Parameter	Construction type
Exterior wall	Brick walls
Roof	Metal surfacing roof
Floor	Slab on grade floor
Glazing	Double glazing

Table 3 shows the information on number of people, lighting and electric equipment power density. The lighting and electric equipment power density follow ASHRAE Standard 90.1, and the number of occupants follows ASHRAE Standard 90.1-2007.

Table 3. Internal heat gain and building operation schedule of the prototype convenience store building model.

Parameter	Value
Lighting (power density)	ASHRAE Standard 90.1
Equipment (power density)	ASHRAE Standard 90.1
Occupancy (number of people)	ASHRAE Standard 90.1-2007
Building operation	Open from 6 a.m. to 11 p.m. (17 hours)

3.2 FLOOR PLAN

The prototype convenience store is assumed to have general merchandise with a broad product mix, simple food service, and fuel, with extended hours of operation. The site and floor layout of the building was developed accounting for the space, location, adjacency, circulation, and clearance requirements specified in convenience store design guides and/or noted in sample layout drawings. Guidance from Gentile (2022) was considered when setting up different stations, refrigeration units and checkout areas (Gentile 2022).

An enclosed office, utility room, and restrooms are placed at the back side of the building with access from inside the store. The inventory storage room, also placed at the back, has access from inside the store as well as outside. The walk-in cooler and freezer are adjacent to the storage. This leaves open space and sides for merchandise and a checkout area towards the front. The reach-in refrigerators and freezers are placed along the back walls against the walk-in cooler and freezers. The sides are reserved for small stations with beverage dispensers, coffee machines, hot food holders, or refrigerated grab-n-go cases, and the center is reserved for shelves with nonperishable items. The front façade of the building is glass with a 7 ft. wide, hinged, double door, entrance without a vestibule.

On the site, four fuel pump islands spaced 22 ft on center are provided under a 90 × 18 ft, 15 ft high canopy. The fuel pump islands are placed at 35 ft from the building to allow for parking and clearance. The shading of the building from the canopy will be modeled.

The typical floor plan is shown in Figure 12, and the space area distribution determined in shown is Table 4. Figure 13 shows the site layout of the convenience store with the gas station.

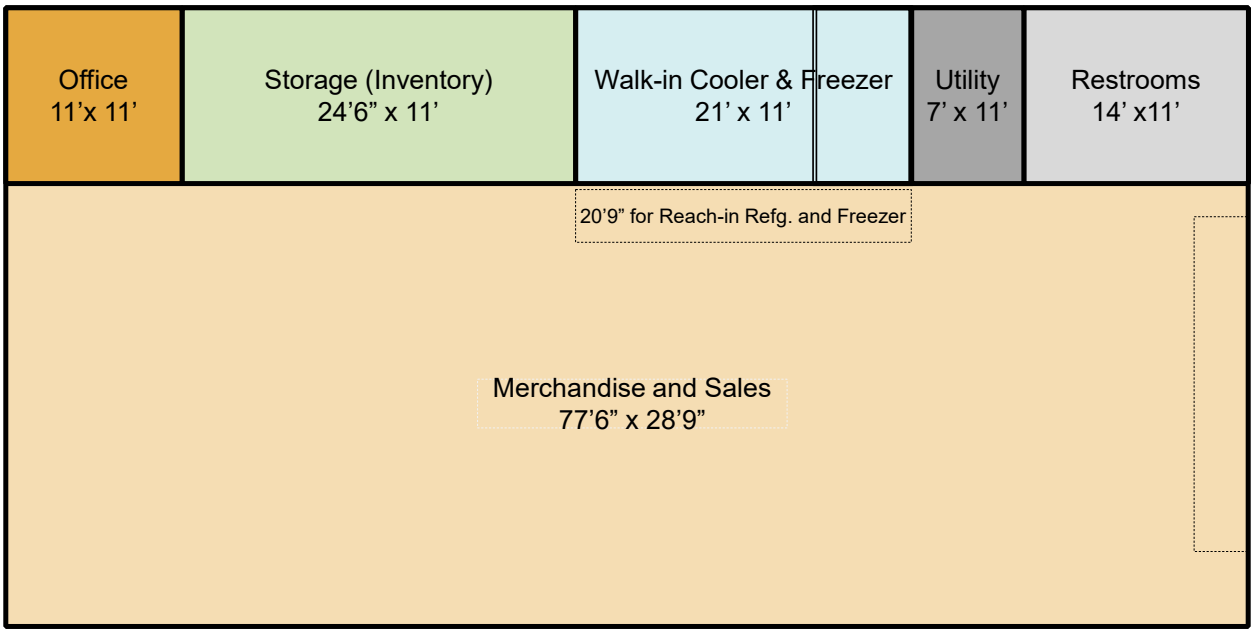


Figure 12. Typical floor layout of the convenience store.

Table 4. Space area distribution of the convenience store.

Space type	Spaces	Floor area (ft^2)	Percentage (%)
Retail	Merchandize, sales, coffee bar/deli/bakery	2,150	71.6
Refrigerated storage	Walk-in cooler	165	5.5
	Walk-in freezer	66	2.2
Office (enclosed)	Office	121	4
Storage	Storage (inventory)	270	9
Utility	Utility	77	2.6
Restrooms	Restrooms	154	5.1
Total	—	**3,003**	**100**

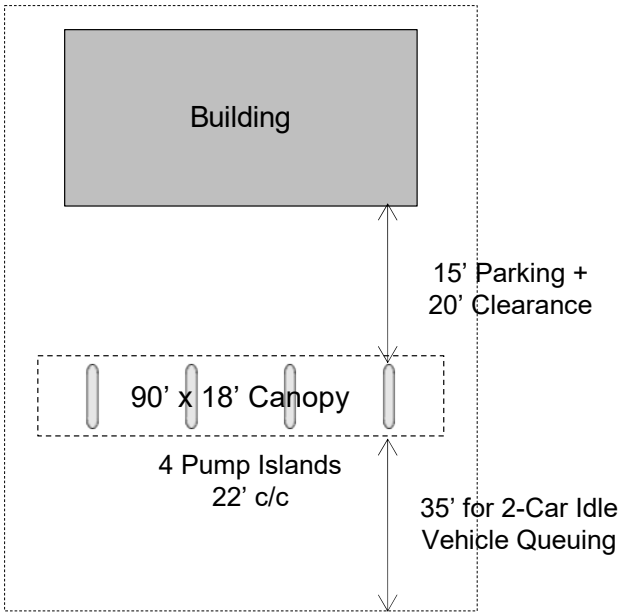


Figure 13. Site layout of convenience store with gas station.

3.3 HVAC SYSTEM AND WATER HEATER SYSTEM

Table 5 shows the HVAC system and water heater system information for the prototype convenience store building model. Based on the review of the 2012 CBECS dataset, 2018 CBECS dataset, and the 2015 ASHRAE Handbook–HVAC application (ASHRAE 2015), the ORNL team selected a packaged central unit and packaged air conditioning unit for space heating and cooling. A centralized water heater system was selected since a centralized water heater system is used in more than 70% of existing convenience store buildings in both the 2012 and 2018 CBECS datasets. The operation schedule of the HVAC system and water heater system follows the building operation schedule since both systems operate during occupied hours.

Table 5. Selected HVAC system and water heater system for the prototype convenience store building model.

System	Type	Schedule
Heating system	Packaged central unit	Same as building operation schedule
Cooling system	Packaged air conditioning unit	Same as building operation schedule
Water heater system	Centralized water heater	Same as building operation schedule

3.4 REFRIGERATION SYSTEM

To determine the number of refrigerators and freezers, the actual length and depth of each refrigerated case, and the size of walk-in units, the available depth and length of the floor plan of the prototype model were considered. Based on this information, the number of refrigerators and freezers were determined to be eight closed cases and two walk-in units, as shown in Table 6. The closed cases consist of six coolers and two freezers. These include three types of closed cases and freezer display cases: medium-temperature reach-in cases, low-temperature reach-in ice cream cases, and one low-temperature frozen food case. For the walk-in units, one frozen food walk-in freezer and one dairy/beer walk-in cooler are

included. Table 7 and Table 8 show the location of the cases and walk-in units, their operating temperatures, total case length for each case type, and insulated floor area of each walk-in unit.

Table 6. Summary of refrigeration system of the prototype convenience store building model.

System	No. of units	Schedule
Closed-case refrigerator	6 coolers and 2 freezers	24 hours
Walk-in case refrigerator	2	24 hours

Table 7. Detailed input values for refrigerator and freezer.

Type	Space	Rated capacity (Btu/h·ft)	Operating temperature (°F)	Length
Low-temperature reach-in ice cream	Retail	642.1	-11.02	2 ft 4 in.
Low-temperature reach-in frozen food	Retail	607.0	-4	2 ft 4 in.
Total				**4 ft 8 in.**
Medium-temperature vertical open	Retail	1495.1	33.1	16 ft 3 in.
Total				**16 ft 3 in.**

Table 8. Detailed input values for walk-in units.

Unit	Space	Rated capacity (Btu/h)	Operating temperature (°F)	Insulated floor area (ft^2)
Frozen food walk-In freezer	Retail	6,851.12	-15	66
Dairy/beer walk-in cooler	Retail	12,942.09	35	165

4. CONCLUSIONS

In an effort to expand the current suite of prototype commercial building models, this report presents the convenience store building model characteristics. Multiple sources, including databases, documented projects, and personal communications, were used to define the prototype convenience store building, and a one-story, 3,000 ft^2 building was considered as the prototype convenience store to represent an average-sized convenience store in the United States. The ORNL team defined the operational hours of the convenience store as 17 hours per day.

The selected types of exterior wall, roof, and floor were defined as brick-wall, metal surfacing roof, and slab-on-grade floor, respectively. Double glazing was selected, and the window-to-wall ratio was set as 15% on the front side.

For the system, packaged system was selected, and a centralized water heater was chosen. For refrigeration systems, eight closed cases and two walk-in units were chosen.

In the future, the defined characteristics of the building and HVAC system in this report will be further specified in detail for developing the prototype convenience store building energy model. After developing the prototype convenience store building model, the energy use intensity of the prototype convenience store building model will be compared with CBECS and ENERGY STAR data to verify the simulation results.

5. REFERENCES

Architectrure4Design. 2022. How to design petrol filling stations. https://architecture4design.com/how-to-design-petrol-filling-stations/ (Accessed on December 15, 2022).

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). 2015. Retail Facilities. In ASHRAE Handbook—HVAC Applications. Atlanta, GA: ASHRAE.

Building Energy Codes Program. 2016. Commercial prototype building models. https://www.energycodes.gov/prototype-building-models#Commercial.

Deru, M., et al. 2011. *US Department of Energy Commercial Reference Building Models of the National Building Stock*. NREL/TP-5500-46861. Golden, Colorado: National Renewable Energy Laboratory.

Dutchess County Government. 2013. Convenience Stores With Gas Pumps. https://www.dutchessny.gov/Departments/Planning/Docs/E6-ConvenienceStoresWithGasPumps-BothPages-Optimized.pdf (Accessed on December 15, 2022).

EIA (US Energy Information Administration). 1996. 1992 CBECS Public Use Microdata File. https://www.eia.gov/consumption/commercial/data/1992/index.php?view=microdata.

EIA (US Energy Information Administration). 2015. 2012 CBECS Public Use Microdata File. https://www.eia.gov/consumption/commercial/data/2012/index.php?view=microdata.

EIA (US Energy Information Administration). 2016. Table PBA3, Sum of major fuel consumption totals and gross energy intensities by building activity subcategories, 2012. https://www.eia.gov/consumption/commercial/data/2012/c&e/pdf/pba3.pdf.

EIA (US Energy Information Administration). 2022a. CBECS Building Type Definitions. https://www.eia.gov/consumption/commercial/building-type-definitions.php. (Accessed on December 7, 2022).

EIA (US Energy Information Administration). 2022b. 2018 CBECS Public Use Microdata File. https://www.eia.gov/consumption/commercial/data/2018/index.php?view=microdata.

Gentile, M. 2022. 3 Essential Convenience Store Design & Layout Tips. https://www.partstown.com/about-us/essential-convenience-store-design-layout-tips (Accessed on December 15, 2022).

Manross, M, et al. 1999. Gas Station and Convenience Store Design Guidelines. https://www.scottsdaleaz.gov/Assets/ScottsdaleAZ/Design/Gas+Station+and+Convenience+Store+Design+Guidelines.pdf (Accessed on December 15, 2022).

NACS. 2022. What is the convenience store? https://www.convenience.org/Research/What-is-a-Convenience-Store (Accessed on December 15, 2022).

NACS/NielsenIQ. 2022. Global Convenience Store Industry Report. https://www.convenience.org/Media/Daily/2022/Aug/9/2-NielsenIQ-NACS-Release-Industry-Report_Research.

SeaTac Municipal Code. 2022. Chapter 17.36. Gasoline/service station and convenience store lighting. https://www.codepublishing.com/WA/SeaTac/html/SeaTac17/SeaTac1736.html (Accessed on December 15, 2022).

Stanton, P., and Friedman, K. 2016. Gas Station Canopies: Analysis & Recommendations. https://cdn.pompanobeachfl.gov/city/pages/planning_zoning/Text%20Amendments,%20Gasoline%20Filling%20Station%20Canopies.pdf (Accessed on December 15, 2022).

TACHYON. 2020. Lighting Design Standards for Gas Station. https://tachyonlight.com/lighting-design-standards-for-gas-station/ (Accessed on December 15, 2022).

USDOE (US Department of Energy). 2022. Commercial Prototype Building Models. Building Energy Codes Program. https://www.energycodes.gov/prototype-building-models#Commercial.

WBDG (Whole Building Design Guide). 2022. UFC 3-460-01 Design: Petroleum Fuel Facilities, With Change 2. https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-460-01 (Accessed on December 15, 2022).