

Applying Solar Energy to Food Trucks

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Abstract

Ecofriendly is moving to food trucks to save costs with renewables and provide earth-friendly food service. Many restaurants and cafés are becoming environmentally inclined or ‘green’; so are food trucks. Some chefs want to do more than select a menu with food that is local, healthy and sustainably grown/produced. They are also looking at energy efficiency and renewables to safely preserve food, lower operating costs, be more mobile and make their kitchens more comfortable work environments.

All food trucks have a power cord that ties to utility, called ‘shore power’. To be mobile, food trucks typically have fossil fuel generators to supply power while on the move or stationed at a remote site. Solar energy is another possible source of power. Solar-electric modules or photovoltaics (PV) can be mounted to the roof, partially or completely powering food truck kitchens. The viability of applying PV depends of the type of food being offered and the size of the kitchen. In any case, solar can meet many of the energy requirements of a typical food truck.

Keywords: *Ecofriendly, environmental, energy efficiency, renewables, solar-electric, photovoltaic, food truck, kitchen, utility power.*

1. Introduction

While food trucks have recently become very popular in the food industry, street or mobile vending has been around for hundreds of years in the form of pushcarts powered by people selling premade items. In the 1690s, Dutch settlers in New York City offered street food in carts as the city grew. As the country grew west in the 1860s, “chuck wagons” or mobile kitchens were created to feed cattle ranch hands. In the 1870s, some chefs of Los Angeles created the “tamaeros” wagon, the precursor of the taco truck mobile kitchen of the twentieth century. In 1891, Charles Palmer patented the “lunch wagon” design for food cooked for local workers, leading to the emergence of the traditional “food truck”. By the 1930s, with advances in technology and widespread use, street vendors in New York were the first to become subject to many regulations. Growing in number after World War II, food trucks were mostly associated with blue-collar workers and immigrant vendors.

Things had changed by 2000, with the rise of the modern food truck culture and creative chefs looking for new ways to use their skills. As local governments took notice, licensing and more regulation began to emerge. By 2010, the National Restaurant Association had addressed mobile food-related standards, practices and products. The Food Network on television introduced the “The Great Food Truck Race,” causing great media attention. Figure 1, shows a food truck cook-out event. Once culinary schools began to add mobile food cooking classes to their curriculum, the industry was here to stay.



Figure 1: Food Truck Cook Off Event

People with entrepreneurial spirit have the ability to incubate new ideas and develop viable businesses. Food trucks do compete with brick and mortar establishments, and have precipitated development of new zoning regulations and local control of street food business operations. Some local governments value these new small businesses and offer friendly taxes and viable regulations. These entities recognize the industry's contribution to assistance with job growth, expanded community markets and promotion of tourism. The industry has come a long way and owners are now looking for better trucks, quieter generators, more eco-friendly power supplies, sustainable and healthy food sources and use of information technology resources.

2. Food Trucks

There are many types of food truck brands, generally designated as offering processed pre-packaged food or partial to full kitchen service. Processed packaged food trucks do not prepare or cook any food; they serve prepackaged snacks like chips, candy bars and bottled drinks. Kitchen service trucks prepare and/or cook food to varying degrees, from cold sandwiches to hot dogs and hamburgers to full meals. The term "food truck" now refers to any vehicle that serves food and can be moved. Many are traditional utility step vans and others are trailers pulled by another vehicle.

3. Food Truck Vehicles

Over the years, vendors have used four types of vehicles: kiosks, carts, trailers and trucks. Kiosks are temporary and moveable structures, and are not usually used for cooking. The kiosk is typically found as a small-wheeled vehicle like a booth on wheels that is human powered. They are not considered 'street legal'. Carts are like wagons. They are also not street legal, but bigger than kiosks and require a vehicle for towing to a new location. Carts are best suited to menus like coffee, hot dogs and ice cream. Trailers are usually outfitted with kitchen equipment and are not self-propelled, and are street legal. They are often self-contained with electricity, cooking appliances, refrigeration, fresh water and holding tanks for waste. A truck generally offers a full kitchen in the bed of a self-propelled utility vehicle. Trucks and trailers are frequently used for catering.

To maximize interest and clientele, food truck owners often target well-publicized social events, fairs, sports events and concerts. Some food truck owners prefer to station their vehicles at prime locations such as a retail store, park, service station, industrial park or street corner and market to locals in the area. Having a semi-permanent location may have advantages to the food truck owner (such as shore power), and customers come to depend on the truck operating like an outdoor restaurant with portable tables and chairs.

4. Inside Space

The typical modern food truck platform is either an enclosed cargo trailer or a utility step-van truck. Trailers come in sizes from 6 to 8 to 10 feet wide and 8 to 26 feet in length with flat or pointed fronts. Trucks come in sizes from 9 feet wide and 10 to 26 feet in length with a cab and engine in front. Length usually goes in 2-foot increments. To lower business starting costs, owners often purchase used trucks rather than new. Delivery trucks owned by local companies work very well because they usually have relatively low miles. In the ideal truck, the body is open inside and made of aluminum that will not rust. There are generally doors in the front, rear and side.

5. Vehicle Engine and Fuel

Trucks typically use step-van vehicles that have an internal combustion engine (ICE) using either petroleum/gasoline or diesel fuel to propel the vehicle. Fossil fuel diesel engines last longer, are more fuel-efficient and require less maintenance than gasoline. However, diesel produces more air pollution than other fuels. Vegetable or bio-diesel is cleaner if the owner has a diesel engine and can make his/her own fuel from waste cooking oil. A gasoline engine can use ethanol E-85 gasoline. Engines can be modified to use other fuels, like propane or natural-gas. Propane and natural gas fuel are cleaner and may be cheaper. However, propane can be dangerous under the right conditions, as the gas is heavier than air, settles to any low point and does not disperse readily. Electric or hybrid electric trucks are available for greater environmental viability and greater fuel economy, but are more expensive. Trailers require a tow vehicle or pickup truck typically powered by a gasoline or diesel engine.

A truck engine can be used as a generator with an add-on inverter/generator device. It has a special alternator that mounts on the truck engine and generates power from the vehicle engine idling, feeding an inverter that can produce 2 to 3 kW of 120 volts AC power.

6. Generators

Still the longtime standard for providing power you can take with you is the ICE generator that uses gasoline, diesel, propane or natural gas fuel. Most food trucks use a fossil fuel (gasoline/diesel) generator to produce utility grade power. In terms of available back up, there are advantages to purchasing a generator that uses the same fuel as the vehicle engine.

Once fuel is determined, decide on a commercial conventional generator or general use portable inverter generator. There are commercial food truck generators that are designed to meet the needs of mobile kitchens. A generator can only produce a certain amount of electricity. A portable generator not mounted onboard will require an extension cord to bring power into the food truck. An onboard generator is hardwired and physically installed into the truck in its own compartment. A commercial generator can supply large wattages sufficient to power all electrical needs and typical operating on voltages of 120/240 without working hard and stressing the machine. The generator needs to handle both resistive loads (heating) and reactive loads (electric motors) as well as higher surge currents during motor starting. When the truck is stationed at a location cooking or parked at the commissary for resupply, the vehicle can use a shore power cable to connect to utility power, thus limiting generator use to just mobile operations. Small, portable generators located outside the vehicle require extension cords to bring power into the vehicle and do present safety issues.

Onboard generators require mechanical and electrical work that should be done by a professional who will address all safety concerns. The generator should not be installed in the interior of the food truck where people work. Generators produce carbon monoxide, so must be installed in a well-ventilated location that meets the latest standards. Everything in the generator installation area must be heat resistant and non-flammable, as generators have a tendency to get hot. Ample air flow to and from the generator is required, as well as a proper exhaust system. Safety is important. Properly directing exhaust seepage and maintaining cooling airflow ventilation is critical. Customers are also impacted by noise and exhaust.

A generator can be integrated into a solar system in a design called 'hybrid'. This could be the right combination to supplement for kitchens with greater than usual loads.

7. Kitchen Design

A chef relies on his/her tools as shown in Figure 2. Picking the right equipment to operate efficiently in a limited space is a challenge in a narrow truck or trailer. There are a variety of possible layouts for ease of cooking and service. Some appliances cannot take the vibration and movement of mobile trucks. Several appliance companies like Serv-ware and True specialize in food truck equipment. Physical size and ventilation must be considered when placing equipment to work in the truck's small space. Heating, cooling and ventilation are important and affect the amount of power to be produced. Cooking exhaust must be properly ventilated and heat removed for safety and comfort. Using propane or natural gas for cooking reduces the size of the generator or solar system. Energy efficient equipment is important for sizing a generator and/or solar system. An all-electric powered food truck gives the possibility of vending indoors.

8. Operating Requirements

In a restaurant or café, the chef may have adequate space for all the equipment he/she may want. A food truck is limited in space, depending on the type of food being offered. This report lists typical tools found in modern food trucks. Table 1 shows many appliances, their loads and theoretical hours of operation. Operating times are chef-dependent. Some loads will be 24 hours, like a refrigerator, as food needs to be kept cold continuously. Five hours is allocated for cooking for each event shift. Prep time is allocated 3 hours, with the assumption that there is no cooking when salads are prepared. The security camera is allocated 12 hours to include prep, setup and cooking work times.



Figure 2: Food Truck Layout and Service

Table 1: Cooking Tools Operation and Power

Chef Tool – electric appliance	Voltage	Hours of Usage	Wattage
Stereo/ CD/ radio	120	5	200
TV display-computer	120	6	300
Rooftop AC	120/240	4	1920
Window curtain	120	5	500
Exhaust hood – fans	120	6	200
Vent fans	120	8	146
Cameras/security	120	12	250
Lights internal	120	8	200
Lights external	120	5	500
Fire suppression system	120	24/1	20/1000
Cash register	120	5	150
Blender	120	2	300
Coffee pot	120	5	1165
Heat lamps	120	5	250
Hot display case	120	5	250
Bun toaster	120	5	1000
Steam table	120	5	1500
Griddle	120	5	3000
Microwave	120	1	1500
Panini press	120	1	1500
Rice cooker	120	6	1500
Convection oven	120/240	6	700
Hot water heater	120/240	5	1500/2500
Water pump	120	1	50
Ice chest	120	24	1500
Refrigerator / display case	120	24	420
Salad / sandwich refrigerator	120	24	725
Beverage cooler	120	24	420
Freezer	120	24	660
Ice cream –icee maker	120	8	620

9. Meeting the Load

Whether sizing the utility load for a brick and mortar restaurant or a food truck powered by a generator or a solar power system, calculations are made the same way. How much power will be needed from the electrical service? The maximum overall power requirements of all of the electrical appliances that will be used at the same time will need to be determined. Many common appliance values are found on the appliance stamp or tag nameplate. The appliance users manual will also provide the starting and running wattage, voltage, and current in amps. Starting surge amps are different from running amps and allowance needs to be made. Typical electrical calculations can be made using: watts = volts x amps and amps = watts/volts.

Propane is used for most cooking with grills, griddles, ovens and stoves. Therefore, propane-fueled appliances do not add directly to the electrical load, but indirectly they add to the cooling load for the fans and AC. Hot water can be provided by propane, natural gas or solar hot water heaters, adding to generator load. Appliance operating times typically run from 4 to 8 hours for an event that requires 2 to 4 hours to prep. While parking at the commissary during prepping, or closed on weekends, the vehicle should be connected to utility power. Refrigerators present a continuous load and the air conditioning system is the biggest, whether operating on shore power or the generator or other energy source.

Air conditioning unit energy demands makes solar powering a food truck challenging. Having the right exhaust fans and enough of them placed at the right locations to remove heat from propane cooking is the design issue. It does not make sense to run fans and the AC unit at the same time, as the fans draw out the cool air, wasting energy. Heat shields and air windows can assist with limiting heat build-up and reflection of heat to be removed.

10. Solar Power Supply

Let's consider three categories of food trucks and evaluate the load and size of a solar system to fit on the roof of the vehicle. Consider the loads for a typical Ice Cream, Hot Dog and Gourmet food truck and the size of the power supply needed to meet that vehicle's energy needs with a PV system as shown in Table 2. There are over 30 categories.

Table 2: Food Truck Categories/Three Types – Appliances and Loads

Load type	Ice cream (watts)	Hot Dogs (watts)	Gourmet (watts)
Lights	800	800	800
Sign	400	400	400
Fans	1200	1200	1200
Freezer	660	0	0
Refrigerator	0	3360	3360
Oven	0	0	5760
Fire Suppression	0	1440	1440
Total energy load/day	3060	7200	12,960

Photovoltaic modules come in various sizes based on the wattage, voltage and efficiency of the module. Power modules for utility application have higher efficiencies and are physically larger modules than battery charging modules. Consideration needs to be given to mounting the modules flat, tilted or extended. Flat has the advantage of not having to align in the direction of the sun, but generally gives less production. Tilted or extended modules may reach beyond the roof size and need to be aligned with the sun, which affects how the food truck is parked for an event. Tilting and extending can add up to 30 percent more production.

Modules come in efficiencies from 13 to 21 percent, with most utility modules averaging around 17. There are many physical sizes, from 1 foot square to 3.5 feet wide by 6 feet long. Each produces various outputs in watts, voltage and current. The watts per square foot can be determined for each module from manufacturer's specifications and range from 12 to 18 watts/sq ft. Table 3 gives the total

watt per roof size using an average of 16 watts/sq ft for this application. The PV can be extended beyond the roof area for more production.

The roof area of the food truck may contain exhaust fans, skylights, air conditioning and other equipment that will take up space. Most of these items are 1.5 to 2 feet wide for an area of 2.25 sq ft and 4 sq ft used. After subtracting the roof-mounted items, the size of useful area for photovoltaic modules can be calculated.

Table 3. Useful Space by Square Feet and Watts

<i>Trailer/truck length</i>	10	12	14	16	18	20	22	24
<i>Trailer 8 width area</i>	80	96	112	128	144	160	176	192
<i>Truck 9 width area</i>	90	108	126	144	162	180	198	216
<i>Total Photovoltaic DC watts</i>	1440	1728	2016	2304	2592	2880	3168	3456

Solar radiation is different depending on location on the earth. The National Renewable Energy Laboratory provides solar data printed in the Solar Radiation Data Manual for Flat Plate Collectors. A few common sites have hourly data: LA = 4.4 to 6.6, Miami = 4.7 to 6.1, NYC = 3.2 to 5.6 for full sun hours.

Solar works when the sun is shining, whether providing solar thermal (hot water) or solar- photovoltaic (electric) power. PV modules produce DC current that is converted to AC current by an inverter. A charge controller in the inverter package can maintain a battery for 24-hour load operation.

11. Example PV Design

In Table 2, the gourmet example uses an 18-foot truck. An Amerisolar AS-6P30 module at 270 watts was selected with a total of 9 modules for a 2,430 watt DC array. In Florida, this array would produce about 16,038 watts per day with an average radiation of 6.6 peak sun hours. If we assume the PV system has an efficiency loss of 20 percent, then 13,200 watts produced is greater than the load of 12,960 watts; therefore, the PV meets the load and works per assumptions for this example.

In this example, the 18-foot gourmet food truck operating for 6 hours a day could function completely on solar power, using propane for cooking. This implies the other two food trucks of similar or less size will also work on solar energy. Several inverter manufacturers would work in this example, but we chose an Outback Flexpower 3648 that interfaces with generator and utility power, as system shown in Figure 3. Because the vehicle moves around and has several parking locations with shore power, there is no net metering capability. This design provides a utility power cable to connect to a 30 amp utility receptacle when parked. When mobile cooking at an event, the PV system powers the vehicle kitchen, but if there is a greater power demand, then the PV system starts the generator to charge the battery. Once the generator has charged the battery, it can be shut down and the food truck can again run off PV.

12. What is Being Done

Many food truck associations across the country offer services to street vendors and promote food truck operations as professional businesses. Manufacturers and outfitters now have several years of experience with building and equipping trucks and trailers. It is estimated that over 5000 food trucks are currently operating in the country. Rather than people hunting their favorite food all over the area, these mobile cafes go to where the people are.

In surveying food truck associations and national media, over a dozen solar powered food trucks were found. Ecofriendly has taken to the street kitchens by more than just healthy food. Small snack trucks are the easiest to equip with solar, as the electrical load is small as compared to the roof area. Trucks with small kitchens and some full-service trucks are doable. Larger kitchen trucks can be a challenge, especially if the chef does not intend to monitor the loads. The combination of a PV system and generator, with the generator for battery charging, is the best option if the expense can be accommodated. The biggest complaints about traditional generators are the noises and exhaust

prevalent while eating. New York City is studying the idea of creating food truck centers with plug-in power stations to reduce the pollution generated by having so many food trucks in a central location. More change is coming, and solar powered food trucks will be part of that.

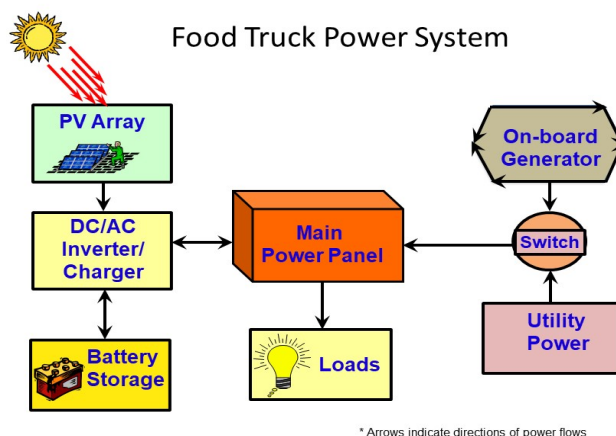


Figure 3: Food Truck Power System Components

13. Conclusion

Time brings many changes and the food truck boom is one. From ice cream trucks to full kitchens with gourmet meals, food trucks offer new and varied eating choices people would have never have imagined a few years ago.

Since 1954, the cost of photovoltaics has gone down each year and quality and performance have gone up. In the past few years, some environmentally inclined chefs have installed PV systems on their food trucks. The question is, 'How viable is it?' The answer is, 'It depends.' Small, limited kitchens with minor loads can be powered by solar fairly easily with enough roof space. Powering full kitchens with air conditioning may not be practical in the summer. If the owner is shrewd and the solar installer clever, some solar food truck concepts will work. One possibility is using solar primarily during the temperate season and during times when limited loads are being used. Energy management may be more than what the chef is willing to do, but some PV systems can be automated to preform energy management tasks.

In this study, I followed the idea, concept, design, construction and start up operation of the food truck project of Robert Young, to bring healthy local food from farm to plate with Hayburner Food Truck. The proposed PV system can power the food truck operations completely until the air conditioner comes on in the summer; then the generator or shore power can recharge the battery and go back to solar power. This design uses minimal generator operation, perhaps an hour per event, rather than continuously. The PV system costs \$12 thousand and the generator costs \$6 thousand for a total combined energy system cost of \$18,000. If implemented, the system offers limited noise, pollution-free energy and sustainable operation. Generator-only power has a cheaper installation cost, but overall is expensive when considering fuel and maintenance costs, as well as noise and pollution effects on customers. With energy efficiency practices in food truck design and a hybrid integrated PV design, solar powered food trucks are possible.

14. Acknowledgements

Robert Young III, Chef, inspired me to write this paper and share his dream. Robert had over 15 years as an executive chef in the hotel industry. The truck was built out by Alfredo Cripin, owner of the American Built Food Truck Company. Alfredo has over 8 years of experience building out vehicles using generators. Michael Brown, owner of Solar-Ray with over 15 years' experience, designed a PV system to my specifications that could, theoretically, power this truck.

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