DRAFT Please comment, add to, correct, etc. and contact blackwell@ipropane.com.

Desired Outcome:

Life can be complicated but possible during electrical power outages. There is a range of conveniences all the way from nothing to business-as-usual to mitigate the effects. Obviously minimum planning would include a way to prevent the house plumbing from freezing, draining the pipes or feeding a wood stove. The focus of this piece is generators. In the event of a prolonged outage, there is hardly any generator (including the fuel supply) that is sustainable. Photocells or wind turbines would be a better but much more expensive choice to mitigate a serious and prolonged disaster.

Issues:

1. What expertise is required of the person expected to operate a standby power system?
2. Single-phase or three-phase. The scope of this document is mostly single-phase. The small engine shops that usually sell generators do not sell three-phase. Neither does WW Grainger. I'd suggest that homes with three phase air-conditioning simply add a single-phase window unit in the most used room and live there during outages. Besides, you can plan on you're A/C going out on the eve of the 4th of July long weekend. See Prices on single and three-phase equipment.
3. Noise mitigation. Generators come with varying levels of noise suppression.
4. Fuel choice. (Gasoline, diesel, propane, natural gas) There is some advantage in using the same fuel that is used in your automobiles. One can be drained to operate the other(s). Stored fuel can be used in either.
    a. Gasoline and diesel oligemerize and polymerize (change to solids and slimes) as they sit in their tanks after an initial charge of antioxidants are consumed. Gasoline and diesel are delivered with enough antioxidant to pass a 90 day aging test at 100F and exposed to humid air. The fuel quality will endure longer in cool sealed containers and exposed to dry air if vented. Pennzoil Stabilizer "small engine fuel treatment" is designed to extend the life of fuels to 18 months under these adverse conditions. Better performance can be obtained by adding a ½ dose every 6 months. The shelf life of the Pennzoil product is indefinite within reason (exceeds 5 years but the fresher the better, they say).
    b. An alternative to stabilizer. Gasoline and/or diesel can be kept fresh by pumping or pouring it from the standby generator tanks and storage containers into active automobiles. One such pump can be purchased from WW Grainger (1N423). A fuel filter base and cartridge can be purchased from CarQuest (part numbers 89034 and 89006) which will prevent solids from entering an automobile tank.
    c. Gasoline and diesel also have the worry of leaks polluting the ground.
5. Fuel quantity. Consider that it is not possible to store enough fuel for any contingency. A small generator, lots of fuel and rolling blackouts of your generator are good ways to stretch it out. A natural gas unit would make a fair plan, especially

if a gasoline or propane carburetor were kept on hand to install if and when natural gas is lost.

6. Fuel storage. Fuel should not be stored indoors.
    a. Large amounts of outdoor storage of gasoline and diesel can be done in farm tanks with hoses and nozzles. Smaller amounts can be stored in plastic containers and will degrade less if stored below grade. A catch pan is helpful if a container happens to leak.
    b. Propane can be stored in the typical tank. Tank costs v. quantity make propane storage less attractive than gasoline and diesel. See Prices. Propane remains cleaner than gasoline and diesel because it does not deteriorate with age. Besides, the solids and heavier liquid contaminants remain in the tank. Propane systems have a natural cleaning feature. As propane vapor is burned in the generator, liquid in the tank boils to replace the vapor, which leaves the contaminants in the tank.
    c. Natural gas cannot be reasonably stored but has a good record of being available during electrical outages.
7. Store generator indoors. A unit on wheels can be stored in a warm and dry garage and then rolled outdoors to operate. Garage doors that need power to open complicate this choice a bit.
8. Permanently installed outdoor generators present the problem of keeping the battery and oil warm enough to start when needed. If stored outdoors, one would be tempted to keep the unit warm with a heater. Engine manufacturers can make compromises between lowest recommended temperature to start, heaters and thermostat setting, multi-weight oil, battery size, etc. This paper does not cover any more on this subject. See manufacturer's recommendation.
9. Run outdoors or indoors. If run in indoors, the exhaust needs to be piped outdoors with great confidence that it will not leak fuel or CO indoors. The heat produced by the engine can be an asset as well as a problem.
10. If propane or natural gas is piped indoors, the leakage problem is a larger concern than gasoline or diesel.
11. Permit. The codes generally require a permit to make indoor wiring changes. Commercial installations generally require a licensed electrician to do the work.
12. Keeping the battery charged. If the generator has a battery, a Battery Tender® brand device is very helpful. Red and green lights indicate charging from the house power and status. For example, a bad battery will not indicate with a green light.
13. Durability. Generally standby power plants are designed for occasional use. A customer should plan on replacing a standard gasoline engine every four months if run continuously. If a customer plans to generate all of his electrical power, there are other options outside the scope of this document. For example, a PERC-funded project has developed a Marathon engine designed for continuous operation and recovers heat from the water jacket and exhaust. Its cost and complexity have been so high that no manufacturer has seen a market potential large enough to mass produce these units and reduce the costs to the point of a commercial success. Another PERC-funded project seeks to develop an intermediate-life engine without heat recovery and eventually become part of a photocell hybrid system. PERC is the Propane Education and Research Council.

14. Maintenance of fuel system. To preclude gasoline or diesel from creating a problem from changing to solids and slimes, anti-oxidants can be added on a periodic basis or the fuel can be drained and used in another engine or the engine can be run often enough to keep the fuel relatively fresh. Gasoline also contains residuals that will clog your system after the volatile parts evaporate, particularly a problem in the carburetor, downstream from all the filters, where there are very small orifices designed to regulate flow but catch debris instead. For example, Honda recommends running the engine periodically and/or draining just the carburetor and gas line after each use.
15. Maintenance of battery. Lead-acid batteries generally lose about 5% per month, affecting aging batteries more. Good practices are to: (a) Keep a Battery Tender® or Smart Charger® on the battery. (b) Replace the battery every 6 years or less without a charger. (c) Or test the battery periodically and replace as necessary.
16. Maintenance in general. Homeowners are generally not the best at performing scheduled maintenance. Computer reminders are a good idea. When the power goes out after dark, the prospect of cleaning a carburetor under the light of a flashlight is poor.
17. Ways to connect.
    a. Permanently wire. This requires an electrical permit and in some cases a licensed electrician and a switch to prevent back feeding to the commercial power poles. Simply opening the main breaker from the utility and connecting standby power to the circuit breaker panel is a violation of the *National Electric Code (NFPA-70), 1995 edition,* paragraphs 230-63 and 700-6.
    b. Electric utilities generally disapprove of any generator that can feed power back to their pole and transformer. Manual three-way switches are the common way to preclude this feedback but costly. See Prices. The solar and photovoltaic industries may have UL listed boxes that will parallel standby power to the utility grid or automatically switch entirely to standby power, which I'd expect cost much more than a manual switch. The utility companies say that they do not want their employees electrocuted by a standby generator connected to the grid. Never mind that their rules require them to short out all lines prior to touching. Never mind that no generator can power up the whole grid and, if it tried, its own breaker would blow. One generator could, however, power up the closest transformer if the neighbors were disconnected from it somehow and put about 2400 volts on the primary wires.
    c. Extension cords. The *National Electric Code (NFPA-70), 1995 edition,* paragraph 422-8(c) requires that permanently installed equipment such as furnaces and well pumps be permanently wired. This means you would violate the *National Electric Code* by installing a receptacle and plug to feed power to a permanently installed load so that an extension cordscould be connected.
    d. You should want to keep your house in compliance with the *National Electric Code.* That means do not add anything without a permit unless the addition can easily be undone before showing the house to a real estate person.
18. Overloads. Hardly anyone wants to pay for a generator large enough to start all loads at the same time, which the utility can do. Given the motor starting problem, it

is problematic to switch to standby power with all loads calling for power (see below), depending on the generator.

a. Steady-state load. Each appliance typically has a rated voltage, current and power on its label. The current ratings can be added to estimate the steady-state load. One must obviously buy a generator with a rating high enough to run the loads expected to run at the same time. Keep in mind that almost all appliances operate below their rated loads. For example, a table saw idles until you cut some wood. When you push some wood into it, the motor current goes way up. If you push hard enough, the rated load will be exceeded and the motor will overheat or stall.
b. Starting loads. Running the loads is only part of the equation. Incandescent lights require 7 times running current to start. Some motors with separate starting windings can require 10 times running current to start. Common three phase 5 HP motors require 7 times running current to start. Smaller induction motors can be expected to draw 4 times running current to start. Generators have ratings for momentary (surge) loads also. If one wanted to start all the loads at once, a larger generator would be required. The alternative is to start the loads one at a time. It is also obviously important to have a generator that will start the largest single load.
c. Altitude derating. Altitude reduces the power available from engines. The generator part of a package can produce the same power as sea level except it will not cool as well. You can determine the amount of power needed and buy a generator 33% larger for 8500 ft above mean sea level. The higher you go, the more derating is necessary, requiring a larger generator.
d. Altitude adjustments. Fuel adjustments on gasoline, propane and natural gas engines are necessary to achieve even the derated power output. Sea level jets in the carburetor or sea level adjustments will cause sooting and poor power at high altitudes. Some engines have needle valves that can be adjusted. Some have jets that must be replaced. A problem arises when a dealer is not eager to make these adjustments or does not know how. The desired outcome is to have a unit set for the proper altitude and have all the factory recommendations in writing as to how the altitude adjustment was done and how it can be kept in adjustment or changed in the future if the unit is moved. The best time to get the parts in hand or installed and information from the dealer is before the dealer is paid. Diesel engines may require the injectors to be set for high altitude starting. A non-computerized diesel will assume that sea level air is entering the combustion chambers during cranking and inject maximum fuel, too much for altitude.
e. Other alternatives. Many electric appliances have alternatives. There are gas lights, wood stoves, small RV style gas refrigerators, energy saving light bulbs, etc. Much of the electric load can be shifted to gas appliances or not used at all.

19. If you have really critical loads, put them on UPSs such as a phone system and alarm system, some of which have internal batteries that give one enough time to fire up the generator, which recharges both.

20. If you are building a new house, fresh opportunities are available to accommodate power outages such as sub-panels for critical loads only.

Options:

A. First class is to have a generator that automatically comes on after so many seconds of outage and is installed by a licensed electrician with a permit. It will automatically prioritize loads and shed those it can't power. This system is the most expensive and is hard to take to your next house.
B. Intermediate class is any combination of suggestions above.
C. Economy class is a portable generator that runs on gasoline. You string extension cords through the house when you need it. A special hole in the wall is helpful to avoid leaving a door or window cracked open. A side benefit is that it can be taken to outdoor events needing power, the lake, a construction project, and/or the next house, whatever. If you skip the air-conditioning or use a window unit, everything except the permanently wired appliances such as the furnace can be plugged in, avoiding the need to modify the house wiring. It would be a code violation to connect a furnace to the house wiring with a plug and receptacle but may be allowed in emergencies. Your local electrical inspector can be consulted and may grant a variance. Jefferson County, Colorado will not, according to one inspector.

Prices:

Master generators from WW Grainger cost:

2.5 kW, MGR2900	$699.00	(2005)
6 kW, MGR60001	$1699.00	(2005)

Honda generators from WW Grainger:

10 kW, MGH10000	$2899.00	(2005)

A Honda EB11000 (11kW) (gasoline single-phase generator cost $4376.00 (1997), 20 HP, electric start, air cooled, 615 cc, 120/240 v, 87.5/43.8 amps, 80 dB (pretty loud). Cords, receptacles, etc. cost about $300.00 (1997).

A three pole double throw 60 amp switch, Square D 82352, cost $300.00 (1997).

Centurion brand from WW Grainger:

Automatic starting 15 kW generator	$3199.00	(2005)
Three pole double throw 200 amp automatic switch	$2999.00	(2005).

Available from Wagner Equipment:

A MultiQuip model DCA25SS (super silent) three phase diesel generator sells for $14,700 (2005) It will allegedly run for two or three years, continuous duty, between overhauls. Surge current capacity is allegedly enough to start a full load of motor(s).

An ultra silent model of the above sells for $17,200 (2005).
A 15kW Caterpillar-Olympia propane or natural gas $10,000.00 (2005).
A 40kW Caterpillar-Olympia propane or natural gas $15,000.00 (2005).

A 1000 gallon propane tank costs $1998.00 (2005) from American Welding and Tank.

A 5 gallon plastic gasoline tank costs $8.43 (2005) from WW Grainger.

Worksheet for estimating loads

1. Main breaker panel
    a. Single phase _____ or 3-phase _____
    b. Rating of main breaker, amps _____. Probably 100 or 200 amps.
    c. Main breaker panel inside _____ or outside _____.
    d. List breakers and rating, start another list.
2. List the critical loads in the house
    a. Fire and intrusion alarm? ___
    b. Telephone system? ___
3. List of major electrical loads in the house. List in order of priority both critical loads of any size and loads over 1.2 kW (10 amps).
    a. Refrigerator ?_____
    b. Well pump? _____
    c. Furnace? _____
    d. Garage door operators? _____
    e. _____
    f. _____
    g. _____
    h. _____
4. A/C compressor nameplate data, 3-phase? ____, 1-phase? _____, volts _____, amps _____,
5. Size of breakers that supply the A/C _____.

NOTE ON POWER

Power is energy per second in watts (or kilowatts) (P)
Current is electron flow in amperes (amps) (I)
Voltage is electrical pressure in volts (E)

P = E x I for DC loads and AC loads for heating and lighting

AC motors typically have less power than the above equation would indicate because the current and voltage do not rise, fall and reverse at the same time. A power factor (PF) is applied to the above formula for AC motors to make the equation work. It happens that the PF is the cosine of the angle (in time) that the current lags the voltage.

P = E x I x PF

When in doubt, use 0.8 PF for motors.

There are .746 kW per HP. When in doubt, use 80% efficiency for motors.
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2007-APR-26 Epilogue: The last three days held the longest power outage in the past 40 years for my house. One of my plans was to run the generator for five minutes per hour to charge the phone and alarm system batteries, heat the house, fill the water tank and cool the refrigerator/freezer.

Instead I ran the generator most of the time I was here, with the TV on and enough lights on to be comfortable and get some work done. The power was out for about 10 hours and again for 5 hours. My 11kW generator ran for about 8 hours and used about 8 gallons. That's a lot. The engine is rated at 1.7 gallons per hour at 11kW. My average use is closer to 2 kW, the extra capacity was provided to run the peak loads and start those motors.

Generators have a SWEET SPOT and BITTER SPOTS. A sweet spot is where the generator makes the most electricity for the least amount of fuel, usually around 2/3rd's rated load. A generator is wasteful at idle because it is doing no work. It is wasteful at full power because more energy is blown out the exhaust.

All this means that I should take another look at generators and loads. Some questions to ask are: How long does it take for a refrigerator/freezer to warm up and then cool down when power is applied? How well would an inverter and battery fit into this scheme to keep the very small loads alive such as phones, radio, alarm system and a laptop, while the generator was shut off? How well would photovoltaic cells (PV) fit in?