

# Residential Emergency Power Systems

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An aging population that depends more and more on air conditioning and medical equipment, increased use of electronics requiring uninterrupted power, and increased concerns about the reliability of grid-supplied power have all contributed to a growing demand for home emergency power systems. Grid transmission congestion led to a five-fold increase in electricity purchasing transactions that could not be completed between 1998 and 2002.<sup>1</sup> Also, electric grid capacity margins have decreased significantly over the past twenty years, increasing the risk of an outage. These margins are expected to decrease further over the next decade, from around 20% to 10%.<sup>2</sup>

Several types of residential emergency power systems exist, including:

- Energy storage systems;
- Portable power generators;
- Standby generators; and
- Residential combined heat and power systems (Micro-CHP).

*Table 1* summarizes some key characteristics of the four emergency backup systems discussed.

Residential energy storage systems typically use batteries; although other energy storage methods, such as flywheels, are in development (commercial systems exist). They are relatively simple, but can operate only for limited durations without recharging. Usually, they are only used for short-term supply of small critical loads, such as computers. Whole-house systems are available, but even these larger systems are not usually expected to power large loads, such as air conditioning, electric cooking, and electric heat.

Most portable power generators use low-cost gasoline- or diesel-fueled internal-combustion (IC) engines. They are relatively inexpensive, but can be difficult to set up, need liquid fuel storage, require regular testing and maintenance for reliability, and can only serve plug loads unless hard-wired by an electrician. Because they typically use liquid fuel, they require periodic refueling during an outage to continue providing power, which may not always be feasible. Although some people attempt to

use them for emergency power, e.g., to power a few plug-in appliances during a power outage, they perhaps are best suited for non-emergency, intermittent, grid-independent power.

Standby generators are turnkey power systems that also generally use IC engines, but the similarities to portable power systems end there. They are permanently mounted, usually outdoors, and tend to be larger than portable generators, both physically and in capacity. Most units use natural gas or propane fuel, and start up automatically when grid power fails. They also automatically start periodically to ensure proper functioning.

Unlike portable and standby power generators, Micro-CHP systems provide everyday energy savings by capturing heat rejected from a generator to meet space- or water-heating loads. When designed properly, they also can provide power during a grid outage.<sup>3</sup>

## Sizing Considerations

Current residential emergency power systems have a broad range of capacities, from 1 kW<sub>e</sub> to 40 kW<sub>e</sub>. Small battery uninterruptible power supplies systems can provide as little as 100 W for an hour, but true home emergency power battery systems range from 3.5 kW to 11 kW and provide power to a limited set of appliances for periods ranging from a few hours to as long as a couple of days. Typically, portable power systems have generation capacities of 5 kW<sub>e</sub> or less, while the bulk of the market for standby generators ranges from 5 kW<sub>e</sub> to 12 kW<sub>e</sub>.

Generators can be wired to cover only critical household circuits, or they can provide whole-house backup power. Manufacturers usually provide sizing guidelines that indicate what household loads can be serviced by a given generator capacity. They generally assume that the generator capacity must be sufficient to simultaneously meet the rated power levels of all connected loads.

Analyses show, however, that total *average* demand for a typical U.S. household equals only about 1 kW<sub>e</sub>. Higher energy use typically occurs in the evening and when large loads (e.g., air conditioning or electric cooking) are used. This allows a 1 kW<sub>e</sub> or 2 kW<sub>e</sub> system to meet the critical loads in most homes.

| Characteristic           | Energy Storage   | Portable Generators   | Standby Generators   | Micro-CHP  |
|--------------------------|--|---|--|--|
| Capacity—<br>Loads Met   | A Few Critical Loads<br>For a Limited Time                       | A Few Critical Loads  | All Major Home Loads<br>Or Critical Circuits Only                                | Base Household<br>Electric Load (~1 kW <sub>e</sub> )              |
| Efficiency               | Grid Efficiency Less<br>Round Trip Losses Plus<br>Standby Losses | Governed by Practical<br>Considerations (e.g.,<br>Cost, Heat Rejection,<br>Physical Size) | Generally Higher Than<br>Smaller Portable<br>Generators: Much<br>Lower Than Grid | Minimum of 15% to<br>20% (LHV)<br>For Attractive Energy<br>Savings |
| Lifetime<br>Requirement  | <40,000 Hours Standby,<br><2,000 Hours Operating                 | 1,000–2,000<br>Hours  | 1,000–2,000<br>Hours   | 30,000–40,000<br>Hours   |
| Noise                    | Silent   | No Strict Noise<br>Requirement  | No Strict Noise<br>Requirement   | Must Operate<br>Quietly  |
| Emissions                | No Emissions   | No Strict Emissions<br>Requirements   | No Strict Emissions<br>Requirements  | May Need to Meet<br>Emissions Standards                            |
| Installation<br>Location | Indoor Preferred<br>For Battery Life                             | Outdoor Preferred for<br>Heat Rejection   | Outdoor Preferred for<br>Heat Rejection  | Indoor Preferred for<br>Heat Recovery                              |

Table 1: Comparison of emergency generation options.<sup>4</sup>

For example, the average hourly power draw profile for a 3,000 ft<sup>2</sup> (279 m<sup>2</sup>) home is usually 1 kW or less and rarely exceeds 2kW (Figure 1). Consequently, larger generators operate at a small fraction of their rated capacity at most times, leading to significant part-load efficiency penalties.

Using an intelligent load-management system and a small energy-storage system, it is possible to design a backup power system around the average power draw value instead of a theoretical peak value.<sup>4</sup>

Smaller generators have several key advantages, including:

- smaller physical size;
- lower noise (depending on technology)
- potentially lower cost; and
- improved generation efficiency.

From an energy perspective, maintaining high generation efficiency is particularly important for Micro-CHP systems because they operate for many more hours per year than dedicated emergency power systems.

### Prime Mover Selection

All of the discussed systems except for energy storage use a prime mover to convert fuel to mechanical energy or directly to electrical energy. In doing so, the prime mover also rejects heat—either to the ambient air or to a heat-recovery system that supplements household space and water heating.

While most existing systems use IC engines due to their technical maturity, alternative prime movers such as Stirling

engines, fuel cells, Rankine engines, thermophotovoltaics, and thermoelectric systems are being developed. Each has had reasons why it has yet to achieve widespread market penetration for emergency power provision.

The low generation efficiencies of Rankine engines, thermophotovoltaics, and thermoelectric systems limit their practical application in emergency power systems. In theory, some fuel cells can achieve high generation efficiencies, but they will likely be too expensive for standby use in the near future.

Stirling engines have achieved limited market penetration due to their relative technical immaturity. Recent developments in Stirling technology indicate, however, some significant advantages for emergency power applications. Because Stirling engines use external combustion, their combustion

process can be more readily controlled to limit emissions. External combustion also allows for fuel flexibility. In principle, Stirling engines are inherently less complicated than IC engines and, have the potential to be substantially quieter.

### Energy Savings Potential

On-site power systems that operate only during grid outages inherently increase energy

consumption because they serve loads that would otherwise not be met. Distributed generation systems (systems without heat recovery that also operate during non-emergency periods) only save energy if their generation efficiency exceeds that for grid power (less transmission and distribution losses).

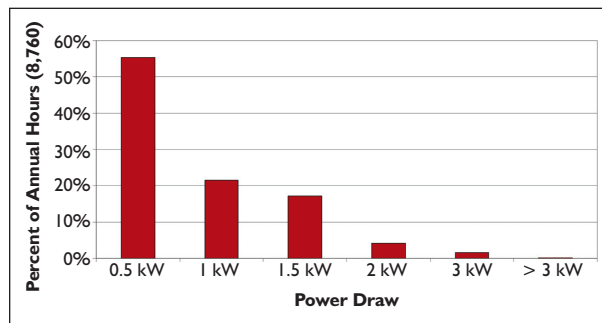


Figure 1: Histogram of hourly average energy use, not including air conditioning.

For residential-scale applications, only solid oxide fuel cell systems hold promise for exceeding the efficiency of the grid, and they have yet to enter the residential market. In addition, energy storage systems have charge and discharge inefficiencies that increase energy consumption.

However, with a proper controls and operating strategy, it may be possible in some utility service areas to lower energy consumption with energy storage systems by charging the system when grid power can be efficiently generated and discharging the system when grid power is least efficient (e.g., during peak-demand periods).

On the other hand, Micro-CHP systems with generation efficiencies between 10% and 25% (lower heating value) can reduce home energy consumption and costs by approximately 10% to 15%, based on an analysis of U.S. homes using natural gas-fired appliances.<sup>4</sup>

### Market Factors

One study estimates the annual U.S. market for all residential-scale generators is about 1 million units and growing. Of these, approximately 200,000 are standby generators.<sup>4</sup>

Energy storage systems can cost between \$7,000 and \$15,000, including installation, depending on the size and complexity of the installation, putting them at the top of price scale. While portable

power systems typically cost around \$300 to \$500, they do not provide convenient and reliable emergency power for many households. Standby generators typically have installed costs that range from \$4,000 to \$6,000 for the most common capacities,<sup>4</sup> while the installed cost of micro-CHP systems now entering the U.S. market is about \$12,000 (not including subsidies and incentives).<sup>5</sup>

### References

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