White Paper

Powering Telephony Over Coax: Generators, Batteries, and Architectures

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Powering Telephony Over Coax: Generators, Batteries, and Architectures

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Telephony standby times, as imposed by Bellcore standards, define an eight-hour minimum standby time as acceptable. As MSOs offer telephony services which displace incumbent and competitive local exchange carriers (ILECs and CLECs), cost-efficient powering techniques must be developed for the cable industry to provide this requisite eight-hour standby time, and even to further extend this standby time well beyond eight hours. Field experience gained from deployed engine-generator (E-G) systems and traditional battery-only standby systems allows realistic comparisons of operational characteristics and ownership costs. Presently, the output power ratings of these E-Gs are typically 3kW, although other power ratings are available. Earlier generations of E-Gs had larger power ratings in support of centralized power nodes. Continuing advances in E-G products seek further increases in power ratings within existing enclosure configurations to create increased power densities.

1. Curbside Engine-Generator Acceptance in Curbside Deployments

An E-G system which can be safely installed in curbside residential right of ways is composed of an inter-operating E-G, E-G feedback control, system coordination and control unit, natural gas supply system, input and exhaust air handling, ignition battery and charger, and enclosure, all with appropriate agency approvals and qualifications. Figure 1 contains a block diagram showing the functional units within an E-G system. Among agency approvals needed for these curbside, public right of way locations are the appropriate Uniform Building Codes (UBC), Occupational Safety and Health Administration (OSHA), Underwriters Laboratories (UL), and multiple National Fire Protection Association (NFPA) codes. Although local and regional inspectors can often have various interpretations and biases regarding these code approvals, the product certification for code compliance is a critical success factor in gaining agreement from local inspectors for placement in curbside easements and other public locations.

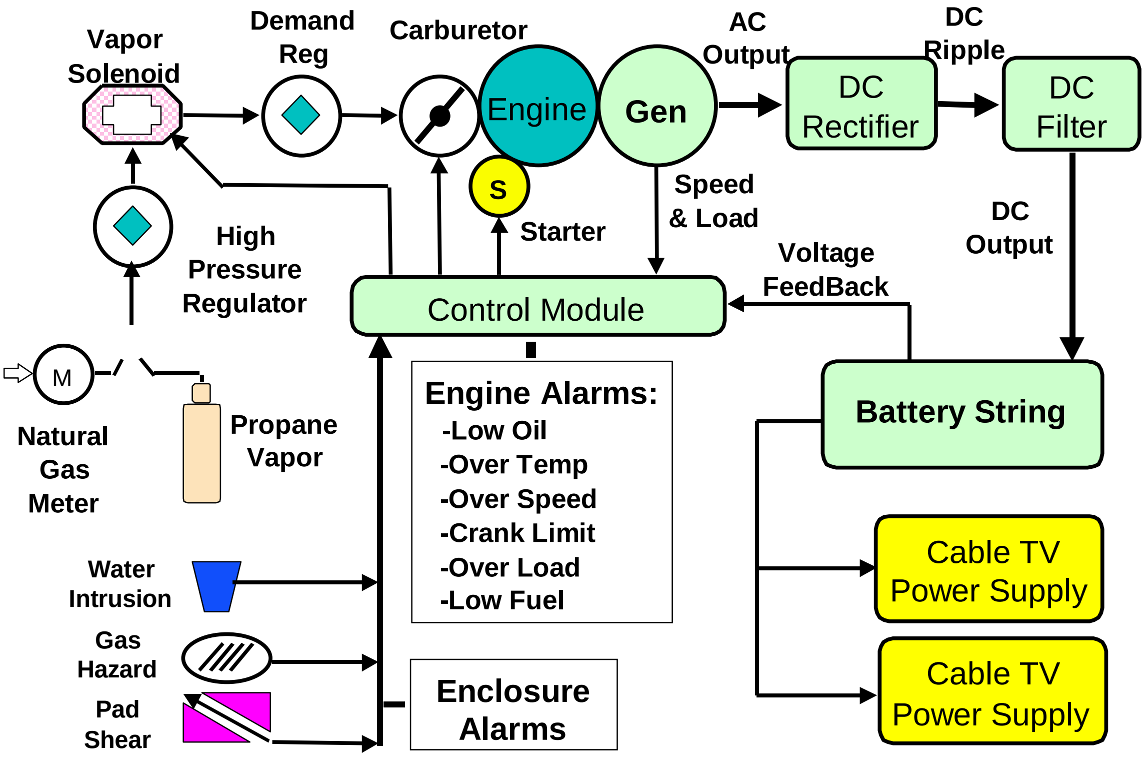

Figure 1. Functional block diagram of E-G system components and subsystems.

Figure 2. Sample 3-kW curbside engine generator. Output power is 3-kW with dimensions of 26" width, 44" height, and 24" depth.

Local resistance to widespread installations of these E-Gs is typically a result of the misconception that these curbside E-Gs exhibit noise characteristics similar to commodity-type E-Gs sold through consumer channels for emergency residential power. A demonstration of an operating E-G illustrates the dramatic improvements in sound characteristics brought by the technology used in these curbside E-Gs.

Commodity-type generators have several inherent shortcomings [1] which make then incompatible with the demanding requirements for both curbside installations and communications powering. Furthermore, the curbside E-G systems discussed here are the offspring of several generations of curbside E-G products, along with considerable investments in research and development devoted to producing smaller, quieter products. Typically, showing the local community the agency compliance and the built-in safety systems, along with discussion of the quantity of existing, successful installations, as well as the 67-dBA acoustic noise profile, results in acceptance of these curbside E-G systems.

2. Engine-Generator Characteristics

One physical realization of the E-G block diagram of Fig. 1 is seen in Fig. 2 with the dimensions provided in the caption. Normally, these E-Gs still require a battery string, although this battery string has a standby capacity of one or two hours. The E-G is partnered with a small battery plant for several reasons. After receiving a start command, the E-G requires some short startup period, on the order from ten seconds to thirty seconds, prior to readiness for full-power operation. Furthermore, analysis of the power grid outages shows that numerous outages have a short-term duration, on the order of seconds. Cycling the E-G cranking system though these unneeded startups adds unnecessary wear and tear to the E-G, and each cranking cycle creates a partial discharge on the battery dedicated to E-G cranking. If too many cranking cycles occur with no opportunity for the cranking battery to recharge, eventually the E-G will be unable to crank and a startup failure will occur.

Although either an ac or dc E-G can be deployed, the trend is towards dc. A dc E-G has several cost and performance advantages over an ac E-G. For example, with the high efficiency of a ferroresonant transformer cable TV power supply, the subpar dynamic load response of an ac E-G limits use of an ac E-G to loads which are less than the ac E-G power rating. Alternatively, a dc E-G used in conjunction with a one or two-hour battery plant, can support loads which exceed the E-G rating, with the extra current coming from the dc battery plant. Such an overload is used to illustrate the robustness of a dc E-G to overloads, and should not be taken as a recommendation to design in such overload operation. Figure 3 shows the overload condition-versus-run time multiplier. If the E-G is sized to equal the load, then the ratio between load power and E-G power is unity, and the run-time multiplier found on the y axis is infinite. An E-G which is equal to the load does not require any power from the dc battery string, and thus the E-G can carry the load until it is time to service the E-G regardless of the size of the battery plant. Another example uses a typical two-hour battery plant. If a 3-kW E-G is used for a 4-kW load, the overload ratio is $4kW/3kW = 1.25$, and from the graph of Fig. 3, the run-time multiplier is 4. Thus the

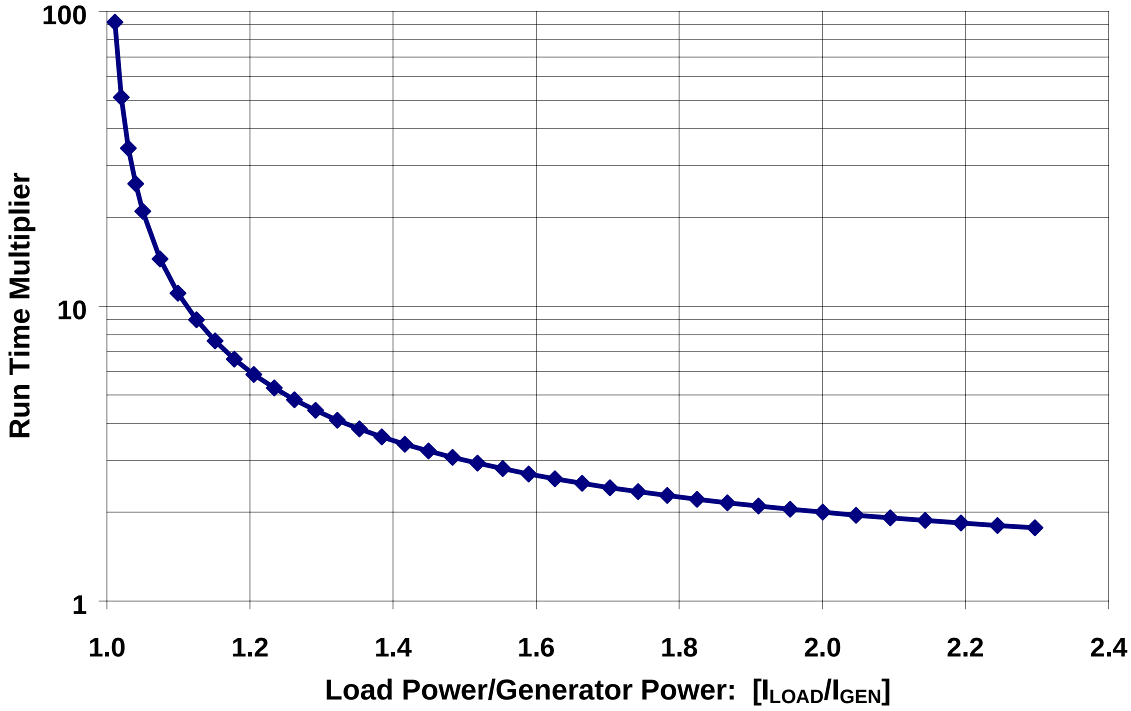

Figure 3. Battery plant run time extention with a dc E-G operating at overload.

two-hour battery plant operating with a 3-kW E-G is capable of supporting a 4kW load for eight hours. As the E-G is undersized further, the extensions to the run time of the battery–only system become less.

Audible sound characteristics of these curbside E-Gs have been aggressively addressed. Engine-generator products being deployed today exhibit audible sound levels of 67-dBA using a four-point average, measured at a distance of five feet. Normal conversations can be carried out within five feet of the E-G, and often it can be difficult to detect E-G operation given any ambient noise, such as a passing automobile.

The E-G offers a truly different standard for standby times; with E-Gs operating unattended for up to 200 hours, with a normal maintenance interval of 100 hours. It is this 100-hour to 200-hour unattended E-G standby time which is compared with the eight-hour standby time of a battery-only solution. Comparisons of longer or shorter standby times affect the costs of the battery-only option and leave the E-G costs unchanged.

Status monitoring of the E-G is important for reliable network operation. Status monitoring of these E-Gs can be performed using cabling which supports use of existing transponders and transponder systems. Typical alarms issued from the E-G system through conventional transponder system include the operational status of the E-G engine system, i.e., running or not running, and major and minor alarms. An E-G run signal can be issued from the cable headend system to initiate the E-G startup sequence which leads to a running E-G.

3. Initial or First Costs

Engine-generators used in field deployments are found over a wide variety of battery plant standby capacities as well as load power ratings. Because the most common E-G size presently in deployment has a 3-kW power rating, all comparisons made in this paper use a 3-kW dc load. In the later section on comparisons among power nodes, the impact of the E-G power rating on the costs of a power node are explored.

Here the E-G technology is compared with batteries at a fixed 3-kW dc load rating. Since the most common power rating for a cable TV power supply is nominally 1.35kW, a 3-kW E-G has over 100 percent excess capacity when used to provide standby power for a single 1.35-kW power supply. A more effective use of the full 3-kW capacity of an E-G is obtained when the E-G power is applied to two 1.35kW power supplies. The E-G control system is designed to support powering of cable TV power supplies which are

Component	Estimated Costs
3-kW E-G with enclosure:	$4,750
E-G installation:	$2,000
Battery enclosure and installation:	$1,000

Table 1. Costs for various E-G and battery comparisons.

located up to 75 feet from an E-G and other E-G models allow up to 500 feet between the E-G and cable TV power supply. This ability to separate an E-G from the cable TV power supply (or supplies) receiving backup power from the E-G allows the E-G to be placed in a location where natural gas is available or in an area compatible with the extra enclosure space necessary for an internal propane storage system. Often the location of the natural gas grid is not in close physical proximity to the hybrid-fiber coax (HFC) grid.

In preparation for comparisons of the life cycle costs (LCC), the initial costs of four systems are compared, two different battery-only backup scenarios, and two E-G-battery combinations. These four examples are used throughout the paper:

1. An eight-hour battery plant which provides an eight-hour standby at 25°C.
2. An eight-hour battery plant which provides an eight-hour standby at 0°C. This battery plant is approximately 28 percent more expensive than the battery plant which provides an eight-hour standby time at 25°C.
3. An E-G which is accompanied by a two-hour battery plant.
4. An E-G which is accompanied by a one-hour battery plant.

Initial costs are listed in Table 1 for different components of the four systems described above. For a 3-kW load, with an 8-hour battery backup time, 24-kWhrs are needed. As a rough estimate of the quantity of 100-Ahr batteries necessary using the assumption of that 1-kWhr is provided by each battery, 24 batteries are needed, for a initial cost of $2,400. At the colder temperature of 0°C, an 8-hour backup time requires an additional 30 percent battery ampere-hour rating is needed, for an initial cost of $3,077. Initial costs for the much smaller one and two-hour E-G battery plants are based on ratios of the eight-hour battery only solution and do not account for battery capacity change with discharge rates. Initial battery cost for the E-G system with a one-hour battery standby time is thus $300, which when combined with the $4,750 initial cost of the 3-kW E-G produces an E-G coupled with a one-hour battery plant for an initial cost of $5,050. Alternatively, with a two-hour battery plant and an E-G, the initial, capital equipment costs are $5,350.

Initial capital expenditures are not the complete picture however. The installation costs for the four

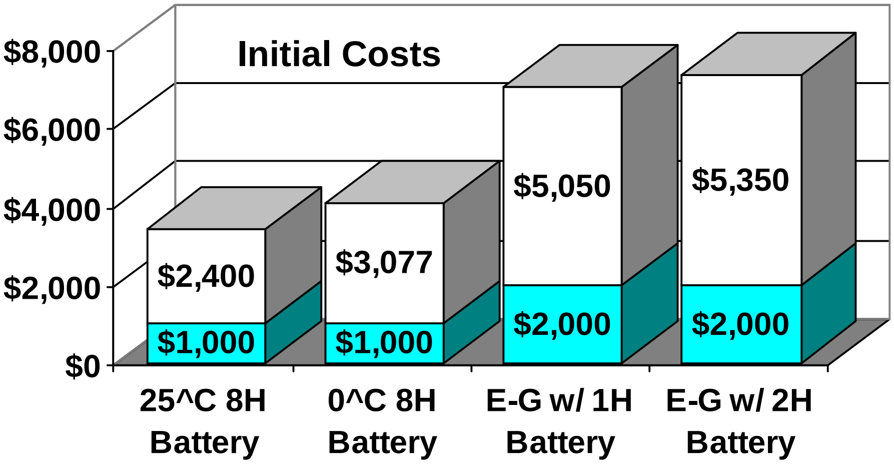

Figure. 4. Initial costs divded into capital and installation for the four 3-kW backup power system examples discussed in the paper. The lower area of each column are the installation costs; the upperare the capital costs.

examples must be included to determine the real first costs of the four examples. Experiences with E-Gs across the country have shown a wide range in installation costs. A large portion of the installation cost is labor, so as local labor rates change, so too do the installation costs. For the modeling here, it is assumed that an E-G can be installed for a $2,000 cost, while the battery-only plant has an installation cost of $1,000. These two installation cost components are added to the capital equipment costs discussed earlier to produce a comparison of the first cost of the four example systems seen in Fig. 4.

4. Life Cycle Cost Comparisons

Life cycle cost (LCC) comparisons are made for the four example systems. Initially, these four examples are compared directly, and the results applied to costs of power nodes later. Again, a power rating of 3kW is used, with a standby time of eight hours for the batteries. The largest variable affecting LCC is the battery life expectancy. Battery lifetimes vary greatly with environmental conditions and other factors. Cable operators often report life expectancies as short as one and one-half years, with more typical expectancies of three and four years. Use of battery technologies specifically intended for cable TV applications has extended these life expectancies to as long as five years. Temperature is the enemy of batteries, with every 10°C rise in temperature creating a 50-percent reduction in battery life expectancy. In order to accommodate this broad range of battery life expectancies, the LCC analyses are performed with battery lifetimes from two to six years.

To calculate E-G expected lifetime, based on the 2,000-hour operating warranty, the predicted annual generator run time is needed. Annual run time results from two sources: maintenance cycle; and operation during power outages in excess of ten minutes. If the ac utility availability is 95 percent, and if 90 percent of the outages lasts less than ten minutes, the generator will operate about 44 hours per year in addition to maintenance cycles. Thus, the total anticipated annual generator run time is approximately 50 hours per year. With a 2,000-hour operating warranty, and following the recommended preventative maintenance schedule, the generators have a theoretical anticipated lifetime of forty years.

For the maintenance costs in the LCC analysis the burdened labor rate of $75 per hour is used. Annual battery maintenance is assumed to consume one hour as does the annual E-G maintenance. The most significant maintenance requirement for the E-G is an oil change after each 100 hours of operation. The E-G oil change consumes approximately one-half hour, and using the estimate of 50 hours annual E-G operating time, this oil change should occur every two years. The costs of this are included in the assumed one-hour annual maintenance for the E-G. The net present value (NPV) is used, assuming a 6% annual cost of capital, to project the fifteen-year LCC costs into a single net present-value cost.

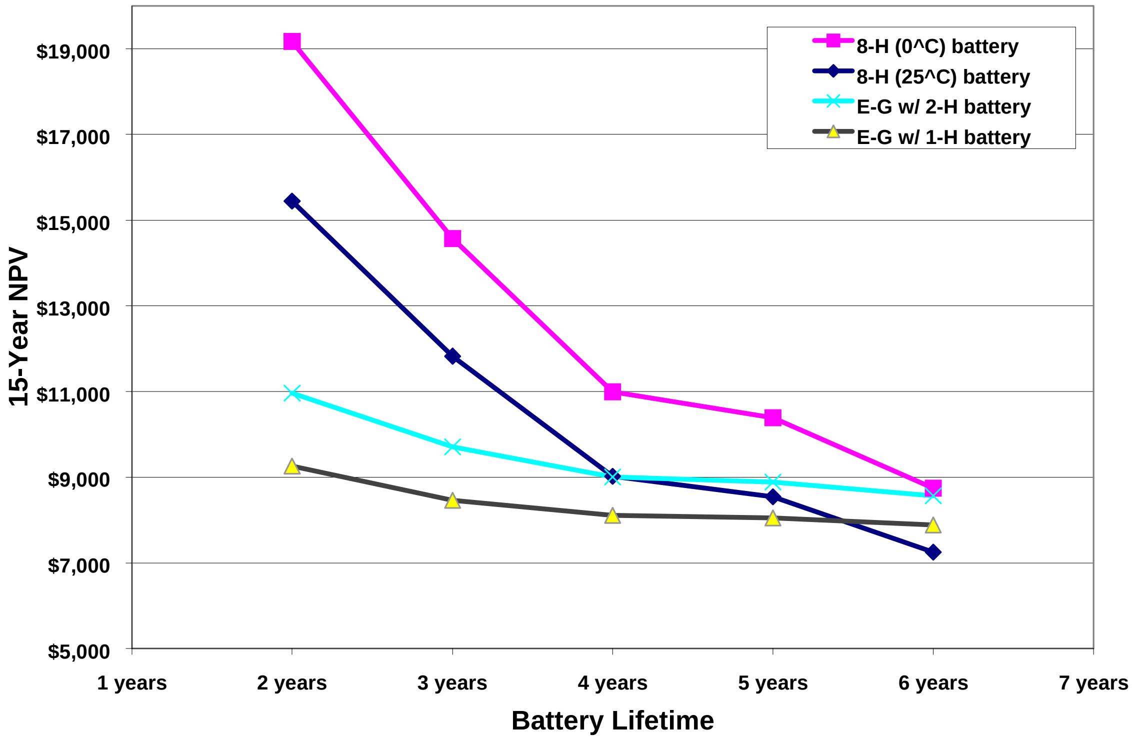

Figure 5. Plot of 15-year life cycle costs for various battery liftimes.

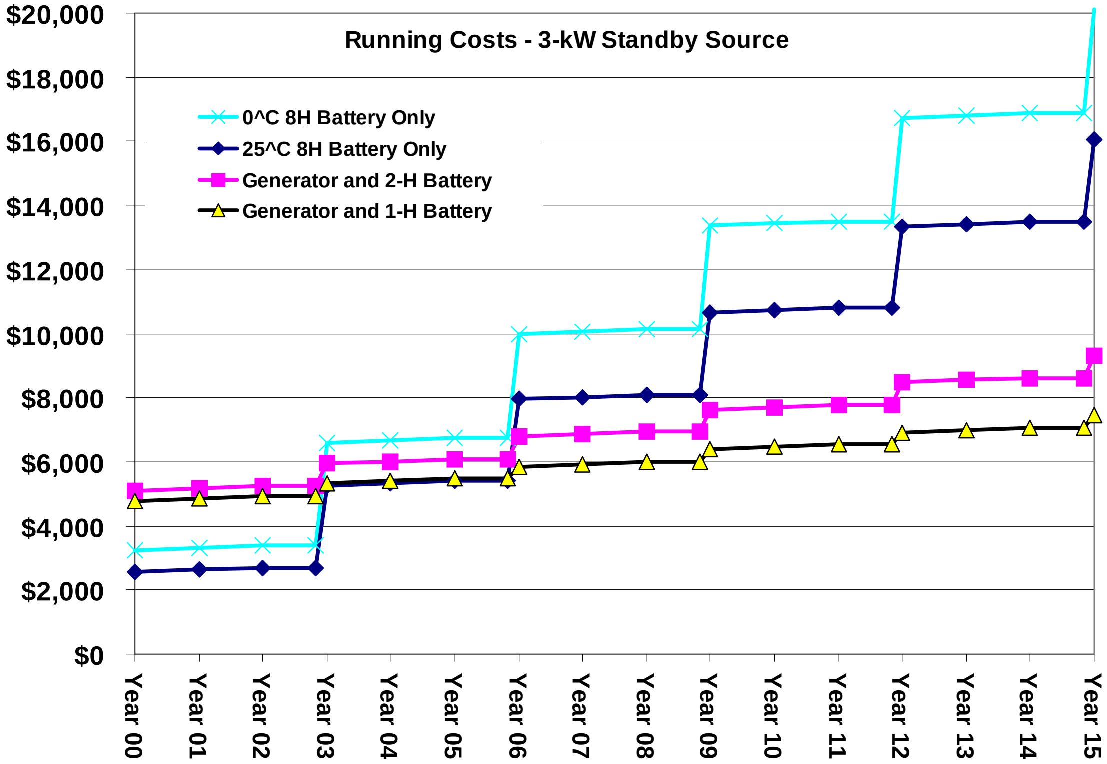

Figure 6. Running costs for a three-year battery life expectancy. Note the eight-hour battery-only system exceeds the costs of an E-G after one battery change out. Longer battery life expectancies move the time for the battery change out farther to the right, shorter battery life expectances move the change out time to the left.

Figure 5 contains a plot of these 15-year LCC costs for the four examples. For shorter battery lifetimes, less than four or five and one-half years, depending on which example is compared, the E-G offers a lower LCC. For these shorter battery lifetimes, the cost savings of the E-G system compared to the battery-only examples are significant, with the LCC cost *difference* amounting to between $4,000 and $10,000 on an approximate expenditure of LCC expenditure of $13,000. Furthermore, with the longer battery lifetimes, the E-G and batteries are approximately equal in LCC, but the E-G offers the 100-hour standby interval, while the batteries can supply the 3-kW load for just eight hours.

An alternative method for looking at LCC is to look at the accrual of costs over time, typically annually. However, a specific expected battery lifetime or life expectancy is needed to create these annual costs. The battery life expectancy changes the scale of the time axis, and rather than plotting numerous examples with the only difference being the battery life expectancy, a single plot using a four-year battery life expectancy is provided as an example in Fig. 6.

Single 1.35-kW Power Supply **Single 3-kW E-G**	25°C Eight-Hour Battery and Power Supply	$4,350
	0°C Eight-Hour Battery and Power Supply	$4,789
	E-G with One-Hour Battery and Power Supply	$8,450
	E-G with Two-Hour Battery and Power Supply	$8,600
Two 1.35-kW Power Supplies **Single 3-kW E-G**	25°C Eight-Hour Battery and Two Power Supplies	$8,700
	0°C Eight-Hour Battery and Two Power Supplies	$9,578
	E-G with One-Hour Battery and Two Power Supplies	$10,150
	E-G with Two-Hour Battery and Two Power Supplies	$10,450

Table 2. Initial costs, including installation, for a single E-G or battery-only standby system feeding either one power supply or two power supplies.

5. E-G Cost Impact on Power Node Costs

A typical pole-mounted cable TV power supply is a 1.35kW supply receiving power from a 36-V or 48-V battery string. In either case, providing an eight-hour standby time is unrealistic because the size of the battery string becomes too large to place on a pole. Placing a single ground-mount E-G in proximity with the pole-mount supply offers a solution for eight-hour backup requirements. With a 1.35-kW cable TV power supply, the 3-kW E-G power capacity is not fully utilized. However, if two of these 1.35-kW power supplies are located together within 75 feet of an E-G site, the 3-kW E-G can be used to provide standby power to the two supplies. Table 2 summarizes these cost comparisons .

Using the data in Table 2, the LCC for the combination of a single 3-kW E-G supplying a single 1.35-kW power supply are presented in Fig. 7 for battery life expectancies between two and six years. For climates and situations where battery life expectancies are a short two years, the E-G offers a lower 15-year LCC, with savings of between $1,000 to $5,000 on an LCC of about $12,000. In situations with battery lifetimes longer than three and one-half years, the single power supply receiving power from an E-G has an LCC which is either on par with the battery-only solution or about $1,000 more than a battery-only solution.

In applications where the E-G can be configured to provide power to two or more power supplies, the advantages of an E-G are most apparent, as seen in Fig. 8. Here, two 1.35-kW supplies are provided with backup power from a single 3-kW E-G. For battery lifetimes ranging from two years up to six years, the single E-G providing standby power to two 1.35-kW power supplies is less costly than a battery-only power node, over a 15-year LCC analysis. This can also be inferred from Figure 5 where the costs of the E-G solution are effectively divided in half as the E-G is shared between the two power supplies. For the

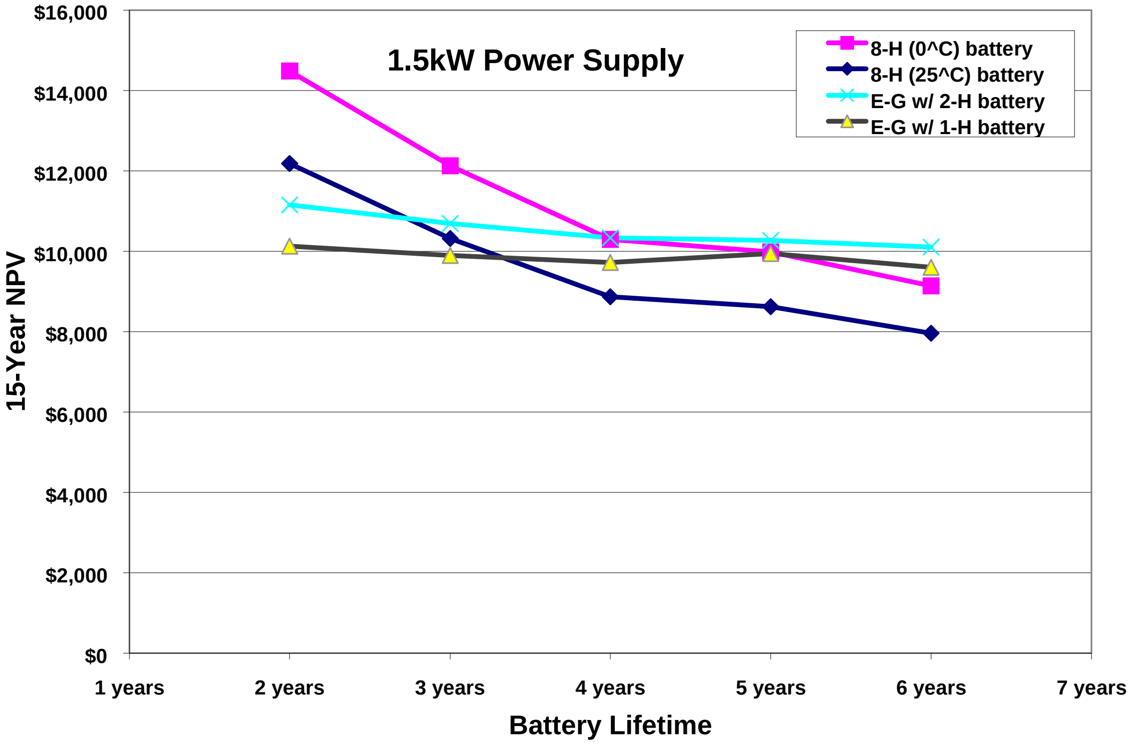

Figure 7. Fifteen-year LCC for a power node with varying battery life expectancies between 2 and 6 years for an eight-hour stanby time with and without a single 3-kW E-G for a single 1.35kW power supply.

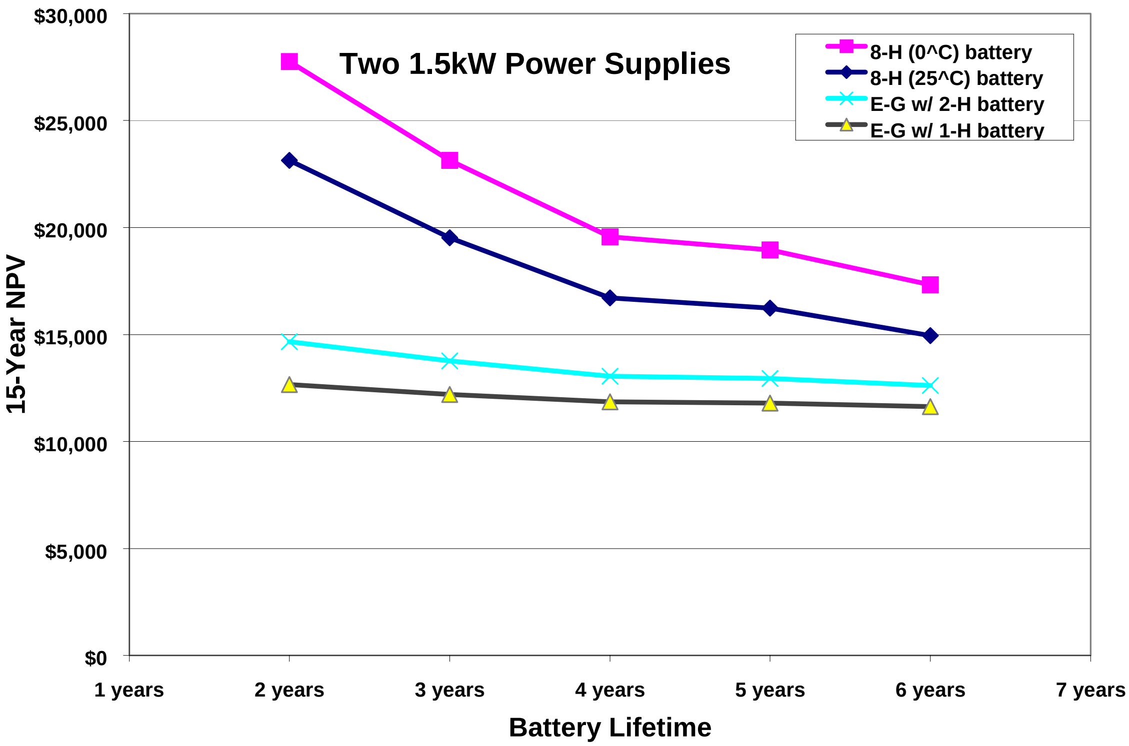

Figure 8. Fifteen-year LCC for a power node with battery life expectancies between 2 and 6 years for an eight-hour stanby time with a single 3-kW E-G or eight-hour battery plant for a two 1.35-kW power supplies .

E-G, the cost difference between Figs. 7 and 8 is the addition of a cable TV power supply with the small, one or two-hour additional battery plant; compare this with the cost difference of the eight-hour battery standby examples which essentially double in costs with the addition of a second cable TV power supply. Cost savings are significant ranging from $5,000 for expected battery lifetimes in excess of 4 years, and increasing to the range of $10,000 for shorter battery lifetimes.

6. Conclusions

For legacy power installations, which support no telephony with a one or two-hour standby period, the installation of a curbside E-G is a cost-effective solution to providing 100 hours and more of backup time — much more than the requisite eight hours. As cable-based telephony markets develop, with telephony services and a growing subscriber base, the E-G offers a convenient method of upgrading standby times.

Reliable power is critical to the rapidly-developing telephony over cable markets. A curbside E-G represents proven, cost effective technology offering lower LCC when compared with conventional battery backup systems. This is especially true when the HFC system architecture allows a single E-G to support two or more cable TV power supplies with backup power. With the necessary alarm and control system in these curbside E-G systems such that they conform with local and national agency approvals, curbside E-Gs are the backup power source for the emerging broadband networks.

References

[1] Thorne, Anthony R., and Sloane, Thomas H., “Engine Generators In Outside Plant Applications,” Intelec 1998, pp. 738 – 745, October, 1998.