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Boulder City Battery Energy Storage Feasibility Study

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Boulder City Battery Energy Storage Feasibility Study

ABSTRACT:

Sandia National Laboratories and Black & Veatch, Inc., conducted a system feasibility study to examine options for placing at Boulder City, Nevada an advanced energy storage system that can store off-peak, hydroelectric generated electricity for use during on-peak times. It evaluated the feasibility and economic impact of an energy storage demonstration project currently under consideration for the Municipal Utility Power Company for the City of Boulder City. The study included evaluations of a proposed site and appropriate advanced battery technologies, pre-conceptual design, artist's conceptions, seasonal electricity load profiles, cost estimates for the battery storage system plus site development and operating costs, and an economic evaluation of the site's payback potential. The study concluded that the Boulder City site is a viable candidate for a Demonstration Unit of an advanced Battery Energy Storage System (BESS) utilizing either Sodium Sulfur, Vanadium Redox, or Zinc Bromine and Regenesys® technologies and that it would provide a net value to the City of Boulder.

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1.0 Introduction and Summary

Black & Veatch Corporation was retained by Sandia National Laboratories to perform a feasibility study on an advanced Battery Energy Storage System (BESS) located at the Hemenway Substation in Boulder City, Nevada. The scope of the work included the following tasks:

- An evaluation of the proposed site,
- An evaluation of advanced battery technologies that are candidates for the application,
- A pre-conceptual design of the BESS on the site,
- Preparation of an artist's conception of the BESS on the site,
- A study of seasonal load profiles resulting in sizing of the BESS,
- A rough estimate of capital and operating costs, and
- An economic evaluation of the BESS in terms of benefits to Boulder City.

Black & Veatch retained Gridwise Engineering Company of Danville, California, to perform the evaluation of advanced battery storage technologies in the context of this project.

1.1 Potential Benefits of Battery Energy Storage Systems

Utility scale Battery Energy Storage Systems provide several benefits. The primary benefit is through load shifting, in which the BESS is charged during off-peak hours when the cost of electricity is relatively low and discharged during on-peak hours, when the value and cost of the electricity generated are comparatively high. Figure 1-1 illustrates how the battery storage facility for Boulder City will be used to shave the peak demand. As illustrated, the actual peak load is reduced as a result of battery operation, and the batteries are recharged during off-peak periods when energy prices are comparatively low. Because the charge/discharge efficiency is about 70 percent, it takes about 1.4 kWh of charging energy to produce 1 kWh of output from the BESS.

The BESS can also provide benefits related to what are commonly termed "ancillary services." The following are typical ancillary services:

Regulation Services — in which energy production is increased or decreased instantaneously to maintain the energy supply and demand balance in real time,

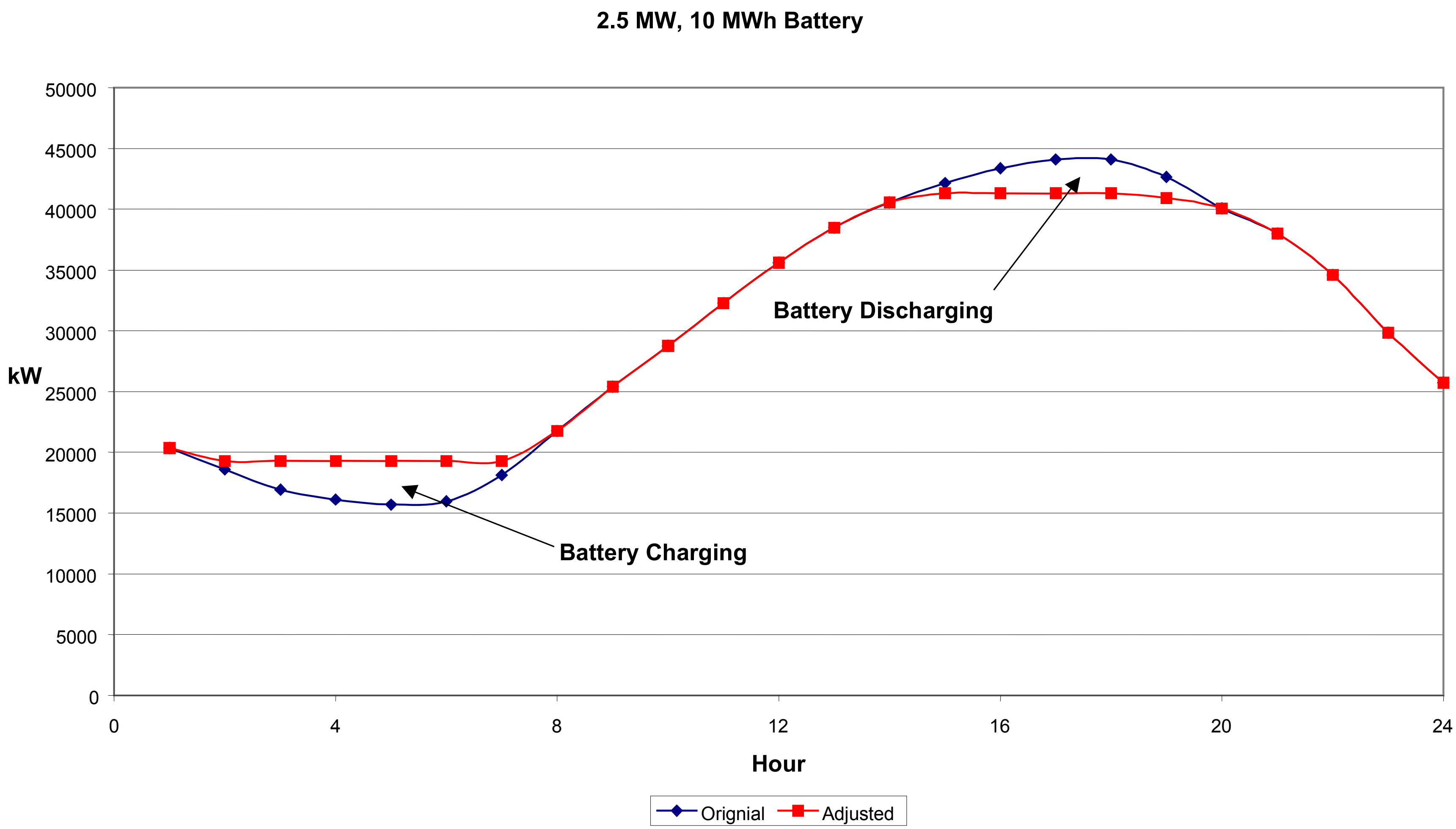

Figure 1-1 Sample Peak Shaving Operation for June 30, 1999.

- **Spinning Reserves** — in which a generating unit is running and has excess capacity that is ready to be dispatched, i.e. spinning, within 10 minutes of receiving a command,
- **Non-Spinning Reserves** — in which a unit is not actually running, but is available and can come on-line in 10 minutes or less, and is capable of running for a minimum time, usually set at two hours.
- **Other Services** — including voltage support, replacement reserve capacity, and black start capability. These services are often procured on a long-term basis and may not be suitable for a unit seeking to occasionally participate in such markets.

In addition, a BESS can eliminate or delay the need for upgrading transmission line capacity to the substation where it is located. Transmission to the substation is increased during low load hours, when the transmission system is capable of handling additional load. The BESS provides supplemental power supply to the distribution system during peak hours, when the transmission system might be at or near its capacity limit. This can also result in lower line losses (I^2R losses).

1.2 Boulder City Project Characteristics

Boulder City ("the City") is a "bedroom" community of about 15,000 people, located just west of Hoover Dam and about 20 miles southeast of Las Vegas. The City was built to house workers on the Hoover Dam. It is now the residence of many federal workers employed by the United States Bureau of Reclamation and the National Park Service, as well as many residents who commute to jobs in the Las Vegas area. The City's electrical load is primarily residential, with some light commercial.

The City owns and operates a municipal electric utility. As a Public Power entity, it has a preference status with the U.S. government. As such, it receives allocations of hydroelectric power from the Hoover and Glen Canyon Dams on the Colorado River. Power from these sources is limited, resulting in the need for the City to purchase power from other, more expensive sources, including Nevada Power Corporation.

1.2.1 Boulder City Electric Loads and Power Sources

Table 1-1 lists the power resources available to Boulder City and the associated costs. The City serves its load by allocating these resources on a merit order, or economic dispatch basis. This means that the lowest cost resources are dispatched first, followed by the next lowest cost, and so forth, until the system load is served.

Table 1-1
Boulder City Power Resources

Resource	Capacity (MW)	Capacity Price ($/kW-mo.)	Energy (MWh)	Energy Price (cents/kWh)	Contract Expiration
Hoover Dam (WAPA)[a]					
Schedule A	20	0.99	80,000	0.754	2017
Schedule B	8.5	0.99	17,870	0.754	2017
SLCA (CRC)[b]					
Summer	5.953	3.44	13,149	0.81	2019
Winter	5.953	3.44	17,419	0.81	2019
Nevada Power Co.					
Amendment 1	Not limited	5.02	Not limited	2.3	
Schedule D			As needed	NPC Marginal Cost[c]	
Reliant Energy	10		Open	5 to 9	2022

Source: City of Boulder City
Notes:
[a] Western Area Power Administration
[b] Salt Lake City Area, Colorado River Commission
[c] Averaged 8.5 cents/kWh in 2000

The lowest cost resources are those provided by the Western Area Power Administration (WAPA) and the Salt Lake City Area Integrated Projects (SLCA/IP), which comes through the Colorado River Commission (CRC). This results in the Schedule A and B WAPA allocations being dispatched first, followed by the SLCA/IP (CRC) capacity. Beyond the City's hydroelectric allocations, purchases are made through the City's Amendment 1 purchases from Nevada Power Company (NPC) and through Schedule D purchases. Purchases from non-utility capacity owned by Reliant are also possible, if scheduled a year in advance.

The ability of Boulder City to receive its full hydroelectric allocation is dependent on water flow resources, including yearly rainfall and snowfall. These hydroelectric resources were sufficient to meet the City's full load for seven months in 1999 and for four months in 2000. To serve the City's load in the remainder of the months, purchases from NPC were required. In 1999, purchases from NPC occurred June through October; and in 2000, May through December.

Amendment 1 purchases from NPC include a capacity charge and an energy charge. When purchases from NPC are made through Amendment 1, energy costs are relatively low. However, it involves a capacity charge element that can result in high incremental costs.

NPC Schedule D purchases are on an as-needed basis, and are priced at the NPC marginal cost. The costs can be substantially higher than Boulder City's other resources because the rate for Schedule D energy is market-based. We anticipate that the BESS demonstration unit will primarily displace the Schedule D purchases.

1.2.2 Proposed Site for the Boulder City BESS Demonstration

The proposed site for the Boulder City BESS Demonstration is on property owned by the city, adjacent to the Hemenway Substation. This substation converts power at 69 kV to 12.47 kV for distribution to local loads. The proposed site is approximately 150 ft by 300 ft. It has been cleared of vegetation and is relatively level. The substation has an empty bay for future expansion, which will facilitate interconnection of the BESS to the substation. The site has ready access from US Highway 93.

1.3 Evaluation of Battery Energy Storage Technologies

Gridwise Engineering Company performed an evaluation of Advanced Battery Energy Storage. A detailed discussion of the evaluation is provided in Section 3 of this report.

Four advanced BESS technologies were considered for the demonstration project:

- Sodium sulfur
- Vanadium Redox
- Zinc Bromine
- Regenesys®

The appropriateness of the technology to the application, the storage sizing requirements, the physical site limitations, potential safety issues, and relative acquisition and operating costs were considered for each technology.

Gridwise, Inc. developed a questionnaire requesting information on various topics and sent it to a number of advanced battery developers. The questionnaire included a request for specific information on costs for a 2.5 MW, 10 MWh demonstration plant.

The following vendors were contacted concerning their battery technology:

- NGK Insulators, Ltd: sodium sulfur

- Powercell Corporation: Zinc bromine
- Sumitomo Electric Industries, Ltd.: Vanadium Redox
- Vanteck (VRB) Technology Corporation: Vanadium Redox
- ZBB Energy Corporation: Zinc Bromine

A copy of the survey sent to each vendor is included in Appendix A.

Innogy Technology Ventures, Ltd., the vendor for the Regenesys® technology, declined to participate in the evaluation because the 2.5 MW, 10 MWh demonstration unit size is below their minimum capacity. Innogy's focus is on larger plants, such as their two 120 MWh plants under construction in the United Kingdom and the United States. Therefore, the Regenesys® technology was not considered for this project.

1.3.1 Technology Readiness

Table 1-2 provides a summary of readiness for the advanced battery technologies. The sodium sulfur technology is the most developed in terms of size and number of commercial installations, annual production capacity, and in terms of UL listing. However, the vanadium redox and zinc bromine technologies have installations of appreciable, though smaller, capacities, with annual production capabilities that could support the Boulder City BESS demonstration project.

Table 1-2
Technology Readiness

	Sodium Sulfur	Vanadium Redox	Zinc Bromine
Field Experience	Over 30 projects ranging from 25 kW to 6 MW. Largest commercial installation is 48 MWh.	Several projects, ranging from 100 kW to 3 MW (pulse power rating). Largest commercial installation is 1.5 MWh.	Several projects, from 50 kW to 250 kW. Largest commercial installation is 400 kWh.
Annual Production Capacity	160 MWh	30 MWh	40 to 70 MWh
Actual Production, Last 12 months	50 MWh	10 MWh	4.5 MWh
UL Listing	Expected to have UL report by early 2002. Electronics would be UL listed.	Electronics only	Electronics and possibly battery

1.3.2 Site Layout and Footprint

Table 1-3 provides information on the physical configuration and footprint of the BESS for each of the technologies. The sodium sulfur battery would come in self-enclosed packages. The other technologies would require building enclosures. All of the technologies would fit within the site boundaries.

Table 1-3
Site Layout and Footprint

	Sodium Sulfur	Vanadium Redox	Zinc Bromine
Structure	Outdoor rated battery enclosures and PCS enclosures.	Building enclosure.	Building enclosure.
Footprint	About 5,000 ft^2	12,000 to 17,000 ft^2	5,000 to 7,000 ft^2

1.3.3 Life and Performance

Life and performance projections for the BESS are contained in Table 1-4. Projected lifetime estimates were based on 100 cycles per year and are widespread. We have assumed a 15-year life for the economic analysis.

Charge/discharge efficiency (AC to AC) varies from 65 percent to 80 percent. For the economic analysis, we used an average efficiency of 70 percent.

Table 1-4
Life and Performance

	Sodium Sulfur	Vanadium Redox	Zinc Bromine
Life	15 years	7 to 15 years	10 to 20 years
Efficiency (AC to AC)	72 percent	70 to 80 percent	65 to 70 percent

1.3.4 Capital and O&M Cost Estimates

Table 1-5 presents vendor estimates for engineering, procurement, and construction (EPC, sometimes referred to as "turnkey") costs and operations and maintenance (O&M) costs. Note that these estimates do not include BESS interconnection with the substation or other site improvements. Each technology vendor indicated that no operators would be required on site. Maintenance requirements differ with the technology, with regular inspections recommended. Vendor estimates of O&M costs varied widely, from about $30,000 per year to $150,000 per year. We have assumed $35,000 per year for the economic analysis.

The survey requested that vendors provide capital cost estimates as EPC cost. It also requested a clear listing of costs that included all batteries, controls, enclosures, engineering, and construction of the BESS unit itself. Table 1-5 provides EPC cost estimates for the 2.5 MW, 10 MWh battery energy package.

Table 1-5
O&M and Capital Costs

	Sodium Sulfur	Vanadium Redox	Zinc Bromine
Operators on-site	None	None	None
Required maintenance	Remote monitoring. Three-year inspections include retorquing terminals, collecting/analyzing OCV data, sensor calibration, system testing.	Quarterly or annual maintenance. Periodic parts replacement (pumps and fans every 5 to 10 years).	Remote monitoring, annual inspections. Specific maintenance items still to be developed.
O&M Cost	$32.5k per year	$50k per year	$30-150k per year
EPC Cost	$12 Million	$10.9 to $11 Million	$5.8 to 8 Million

1.4 Pre-Conceptual Design of BESS Demonstration Unit

Because each of the three technologies evaluated continues to be a candidate for the Boulder City BESS Demonstration Unit, pre-conceptual designs were developed using each. The pre-conceptual design is based on the information provided by the vendors as an EPC building block. As such, in addition to the BESS building block, Black & Veatch provided the following items in the design and cost estimate:

- The BESS building block,
- Electrical and control interconnections with the substation,
- A Visitor's Center,
- Parking lot for the visitor center, and
- Indirect capital costs.

1.4.1 BESS Building Blocks

The BESS building block in each case is assumed to be a complete package. In the conceptual design, the only difference between the technologies is the capital and O&M cost estimate based on the vendor's EPC cost estimates. Two renditions have been prepared, one with the self-enclosed BESS, characteristic of the self-enclosed sodium sulfur system; and the building-enclosed BESS, which is characteristic of the vanadium redox and zinc bromine systems.

1.4.2 Electrical and Control Interconnections

The BESS demonstration unit will be located at the City's 12.47 kV Hemenway Substation. This substation has two 69 to 12.47 kV transformers, fed by two separate 69 kV transmission lines. The substation has a spare vacuum circuit recloser bay, which was reserved for future expansion. The spare bay will be equipped to provide the necessary substation electrical interconnections with the BESS. Controls for the relaying equipment will be housed within an existing control building.

Further detail of the electrical and control interconnections is included in Section 4.

1.4.3 Visitor's Center and Parking Lot

A 2,500 square foot Visitor's Center is included as part of the demonstration project. The Center will be adjacent to U.S. Highway 93, which is a major thoroughfare for tourists visiting the Hoover Dam. An estimated 15 million tourists per year drive by the site. A Visitor's Center will allow public education on battery energy storage system technology and benefits. It could further be used for education on other energy programs supported by the U.S. Department of Energy, such as renewable energy.

The Visitor's Center would include office space for attendants and rest room facilities for visitors. The parking lot has been sized to accommodate parking for 20 vehicles.

1.4.4 Artist's Renditions

Artist's renditions for the demonstration project, including both the self-enclosed and building-enclosed BESS demonstration units, are shown in Figures 1-2 and 1-3, respectively. Less detailed computer generated renditions in Section 4.1 show alternate views of the demonstration unit.

1.4.5 Cost Estimates

Table 1-6 provides a summary of capital cost estimates for the BESS Demonstration Unit for each of the technologies considered.

Figure 1-2 Stand-alone BESS.

Figure 1-3 BESS Enclosed in Building.

Table 1-6
BESS Demonstration Unit Capital Costs
(Thousands of Year 2001 US$)

	Sodium Sulfur	**Vanadium Redox**	**Zinc Bromine**
EPC Battery System Cost	12,000	11,000	5,000 to 8,000
Electrical Upgrade	65	65	65
Facilities	396	396	396
Engineering and Construction Management	450	450	450
Contingency	632	612	323 to 432
Total	13,543	12,523	7,034 to 9,343

Engineering shown in this table is for the electrical interconnect, Visitor's Center, and parking lot only. BESS engineering is considered to be part of the EPC estimate. Contingency for the battery systems is also considered to be part of the EPC estimates and is assumed to be five percent for all the technologies.

We project the operations and maintenance costs to be approximately $35,000 annually. The O&M cost does not include the cost of visitor center attendants.

1.5 Economic Analysis

We estimated the net benefits of the project for Boulder City as a net present worth of the difference between the City's projected benefits and costs. Section 5 provides a more detailed discussion of the economic evaluation.

Project costs comprise the City's allocation of capital-related costs, the cost to operate and maintain the facility, and the cost to recharge the batteries during off-peak periods. Project benefits include reduced purchases of energy and capacity, attributable to the battery storage project. We have not included specific credit for ancillary services because, at present, costs to the city for ancillary services are embedded in the energy and capacity payments.

The current expectation is that the fixed cost contribution of Boulder City to the project will consist of the value of the site for the facility and project support from existing personnel. These are "sunk" costs, in that the site will be at an existing substation already owned by Boulder City and because the project support provided by

City utility personnel will not require additional hires. In the Boulder City Project financial model, no capital-related costs are assigned to Boulder City.

We estimate O&M costs associated with the battery storage unit to be $35,000 per year, escalating at three percent per year. The other cost category is the cost to recharge the batteries during off-peak periods. The study assumed a first year recharging cost of 2.3 cents per kWh ($0.023/kWh), escalating at three percent per year thereafter. Based on an average charge/discharge efficiency of 70 percent for the battery energy storage system, 1.43 kWh of charging energy would need to be purchased during off-peak periods for each kWh of discharge energy provided by the battery energy storage system

Project benefits include the reduced energy and capacity purchases by Boulder City, which result from discharging the battery during peak periods. As discussed in Section 1.1, the BESS is expected to displace Schedule D purchases from NPC at a rate of 9.98 cents/kWh, which is the average Schedule D purchase price in 2000, and escalated to 2004 at four percent per year.

In general, battery lifetime depends on the number of charge/discharge cycles per year. The vendor questionnaire requested lifetime based on 100 charge/discharge cycles per year. Vendor responses varied from seven to 20 years, with 15 years being a median value. For the economic analysis, we modeled 15 years at 100 full cycles per year. This avoided-cost rate continues to be escalated at four percent during the 15 year evaluation period of the financial model. Other input assumptions include a three percent general inflation rate and a six percent present worth discount rate for Boulder City.

The financial model projects that the BESS project will have a net present value cash flow of $424,000 for the 15 years at 100 charge/discharge cycles per year. Under the assumptions of the model, this means that, on a present value basis, Boulder City ratepayers would realize a $424,000 net benefit. This benefit arises because the O&M costs and recharging costs incurred by the City would be less than the benefit of displacing the more costly Schedule D purchases. The benefits to cost ratio is 1.52:1. This ratio is calculated as the present value of the avoided Schedule D purchases divided by the present value of the O&M and recharging costs for Boulder City. This 1.52:1 ratio indicates that the project will be beneficial to Boulder City ratepayers under the Schedule D price assumptions used.

1.6 Conclusions

The following conclusions can be drawn from the feasibility study of a Boulder City BESS Demonstration Unit using advanced battery system technologies.

- Each of the advanced battery system technologies (sodium sulfur, vanadium redox, and zinc bromine) remains a viable candidate.
- The site is appropriate for such a demonstration unit.
- Rough capital cost estimates for BESS demonstration units range from approximately $9.1 million to about $13.3 million.
- Vendor estimates of annual O&M cost estimates range from approximately $30,000 to about $150,000. We believe the $150,000 per year estimate to be high. Four of the five estimates were in the $30,000 to $50,000 per year range.
- Considering capital costs to be "sunk costs," the net present value of the BESS Demonstration Unit to Boulder City is about $424,000.

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2.0 Evaluation of Battery Storage at Boulder City

2.1 Boulder City Loads

Boulder City's load is primarily residential. Figure 2-1 shows load versus time of day for peak days in January, April, June, and October 1999. The curve showing the load for January 28, 1999, is very typical for a winter day in a residential area where most customers heat with electricity. The load begins to increase at about 6:00 a.m. as the customers rise for the day, turn on lights, turn up the thermostats, cook breakfast, and take showers (using electric water heaters). It begins to decrease around 9:00 a.m. as residents leave home for jobs and as heating requirements decrease. The load picks up again at about 6:00 p.m. as the residents return to their homes and begin to cook and turn on lights, televisions, and heaters. The loads begin to decrease later in the evening.

The maximum load for the January day is below 23 MW, essentially requiring only power from the hydroelectric resources.

For April 19, 1999, the nighttime heating load is lower than for January. The load increases at 6:00 a.m. and continues to increase throughout the day, with light uses of air conditioning. As in January, the load never rises above 22 MW, essentially requiring only power from the hydroelectric resources.

For June 30, 1999, the load profile indicates heavy use of air conditioning. For substantial periods of the day, the load is above 32 MW, resulting in a significant need for power purchases from resources other than hydroelectric.

The load for October 1, 1999 is similar in shape to the June 30 profile, although the peak demand is only about 27.5 MW.

We note that, although purchase of non-hydro power for 1999 is required only in the summer and fall, with continued growth of the Boulder City load, non-hydro power purchases could be required during an increasing period of the year, with subsequent load growth over the next few years. Boulder City projects load growths of about 1.5 percent per year for winter months, one percent per year for spring months, three percent per year for summer months, and about two percent per year for fall months.

Figure 2-2 is a load duration curve for 1999, for which Black & Veatch has hourly load data. This curve shows the number of hours in a year that the load is above a certain kW level. Note that the peak demand of about 44,000 kW (44 MW) is reached for only a very few hours per year.

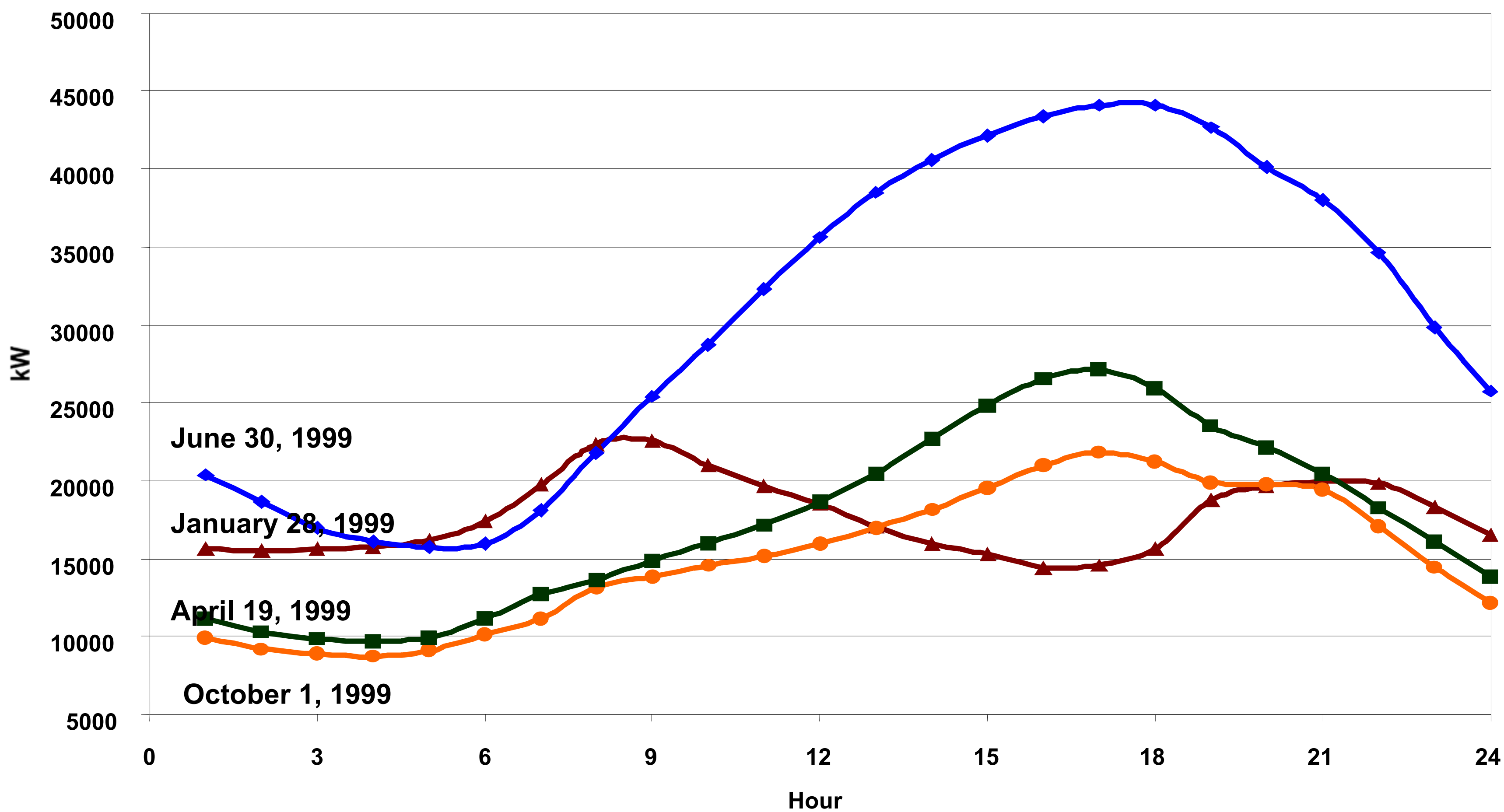


Figure 2-1 Boulder City Load Profiles for Several Peak Days

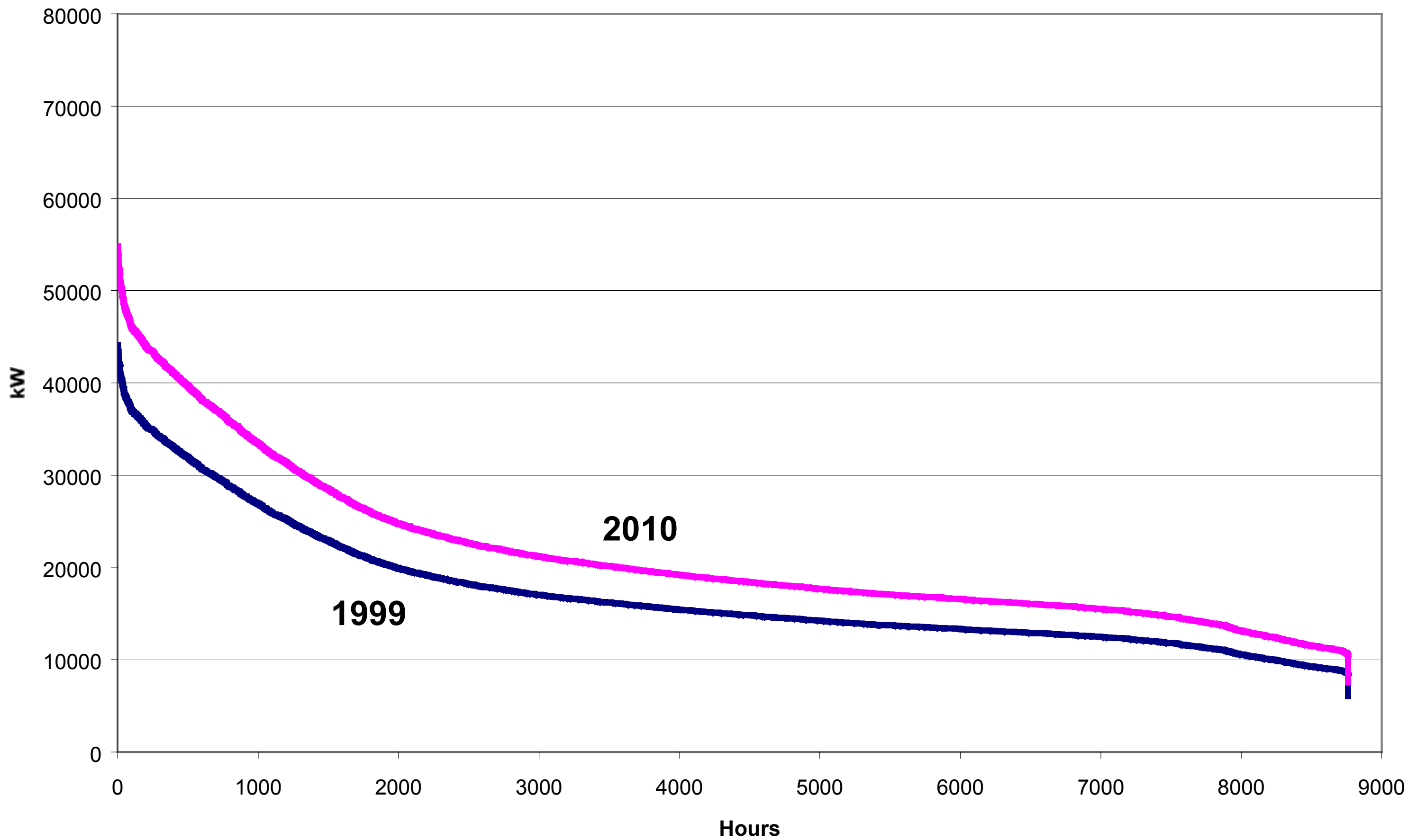


Figure 2-2 Load Duration Curves

Figure 2-2 illustrates that 32,000 kW (32 MW) is reached for approximately 700 hours per year, indicating that non-hydro resources are required for those hours. A load of 10,000 kW (10 MW) is required for over 8,000 hours out of the total of 8,760 hours.

Also plotted on Figure 2-2 is a load duration curve projected for 2010, at an average growth rate of two percent from the 1999 data. We note that, based on the seasonal difference in Boulder City's load growth projections, the curve probably understates the high (summer) peak and might overstate hours during winter and spring. However, in concept, the curve shows that there is a significant increase in the number of hours in the year in which non-hydro purchases of electricity are likely to be required.

A monthly perspective of the load growth between 1999 and 2010 is provided in Figure 2-3, which shows the monthly actual peak load for 1999 and projection by Boulder City of the monthly peak loads for 2010. Note that non-hydro purchases of power will increase substantially by 2010. Boulder City is already purchasing essentially 100 percent of its hydro allotment. Therefore, the increased area under the load duration curve (which represents energy) must be supplied by non-hydro resources. The amount of energy in the peak portion increases substantially. It is the peak portion that is most likely to be higher cost Amendment D (spot market) type purchases.

Boulder City can satisfy the non-hydro requirements through purchase of power, through self generation, through battery storage generation, or a combination of these resources. A detailed generation planning study, modeling Boulder City within the Western Systems Coordinating Council (WSCC), would be required to determine the alternative that costs the least.

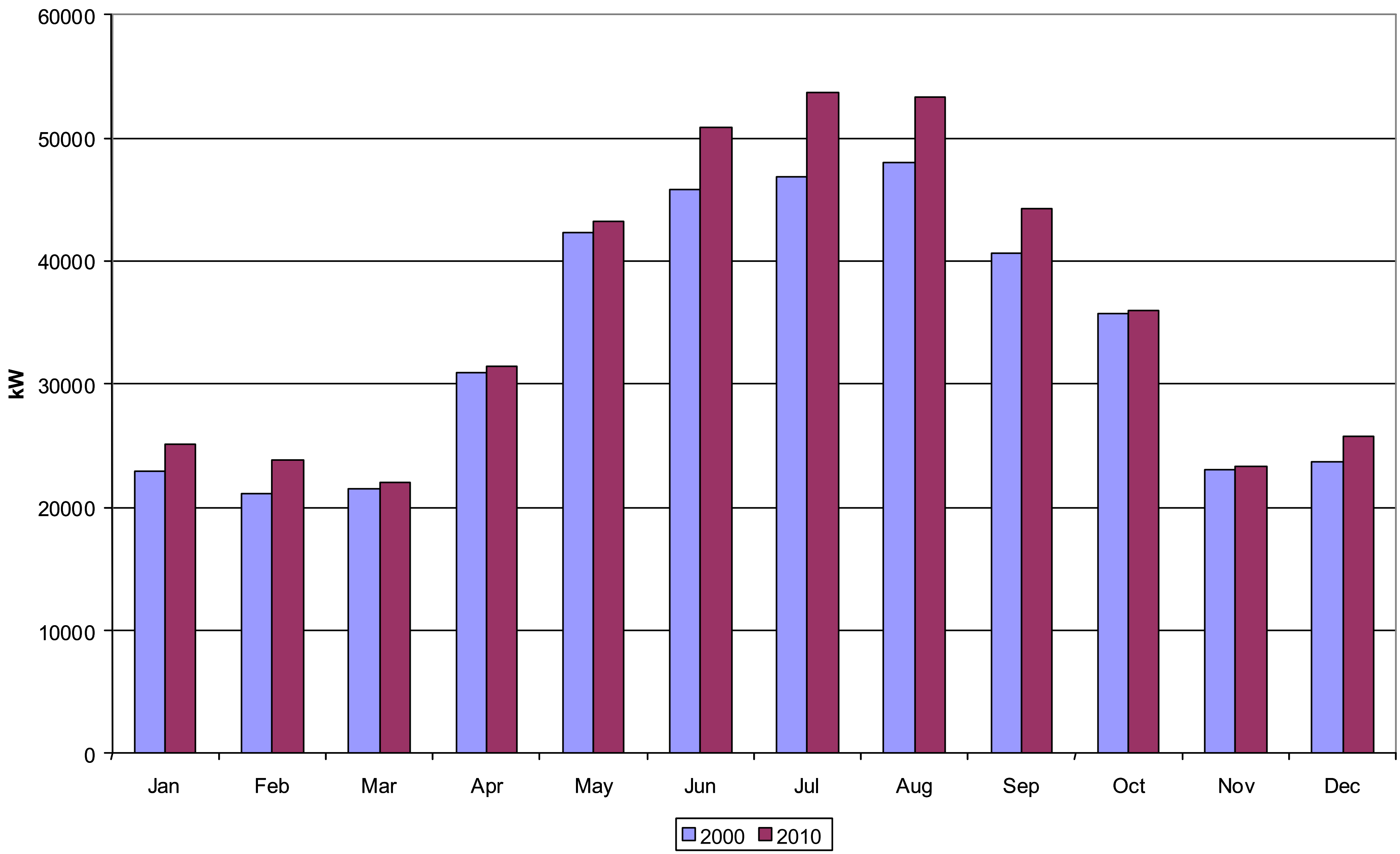
2.2 Battery Energy Storage at Boulder City

The conceptual advantage of battery energy storage for Boulder City is that it capitalizes on the use of relatively inexpensive power during night hours to charge the batteries. The disadvantage is that, currently, battery energy storage systems are still in a developmental stage and capital costs are high, which overcomes the advantage of the low charging cost. However, the proposed battery energy storage system demonstration project at Boulder City, with substantial funding coming from outside sources, becomes a valuable stepping-stone to future commercial systems at numerous potential locations throughout the United States.

2.2.1 Boulder City BESS Demonstration Unit

The BESS demonstration unit would be located at Boulder City's Hemenway Substation. The proposed BESS capacity of 2.5 MW at 10 MWh (four hours of storage at full capacity) is a size that will provide significant demonstration of a utility scale

Figure 2-3 Years 2000 & 2010 Monthly Peak Demand



BESS system. Figure 2-4 shows the charge/discharge impact on the load profile for June 30, the peak day in 1999. As indicated in the graph, charging takes place during the night, while discharge takes place over a six hour period beginning about 3 p.m.

Section 5 contains a discussion of the financial benefit of the demonstration unit for Boulder City.

2.2.2 Viability of Commercial BESS

The economic viability of a commercial-scale BESS at Boulder City or any other site depends on the relative spread between the charging cost of electricity and the value of electricity generated by the system, plus capital and O&M costs. Although nighttime power for Boulder City is primarily hydroelectric power, it is incorrect to consider the charging cost of the BESS to be that of hydroelectric power, because Boulder City currently uses 100 percent of its allotment of hydroelectric energy annually. Therefore, additional power purchased from NPC at Amendment 1 prices (2.3 cents/kWh in year 2000) must be considered as an energy source for charging the battery. Since Boulder City would already be making Amendment 1 capacity payments, no capacity charge would be included in the BESS charging cost.

The value of electricity generated for Boulder City, unless the City were to construct self-generation capabilities, is the purchase price of power. The cost of purchased power in the western US has shown extreme volatility in the past year, both as a result of volatility in the price of natural gas used to generate electricity and because of electricity demand exceeding the supply. As discussed in Section 5, Boulder City's most expensive purchase of electricity was in December 2000, when Schedule D costs were 18.9 cents per kWh. Black & Veatch does not have costs for early 2001, although we note that with winter demand being low, purchases of non-hydro power by Boulder City were likely to be minimal. We note that the California Department of Water Resources, in the first quarter of 2001, bought almost 13 million MWh at an average price of nearly 27 cents per kWh, with nearly two million MWh costing over 40 cents per kWh. However, summer spot market costs of electricity in California have been substantially lower.

More typically, Black & Veatch notes that future pricing for 5/16 contracts (5 days per week, 16 hours per day) for summer months are currently in the range of 15 to 16 cents per kWh, and that such pricing has encouraged significant development of new power generation units. Typically, these units would run about 1,000 hours per year.

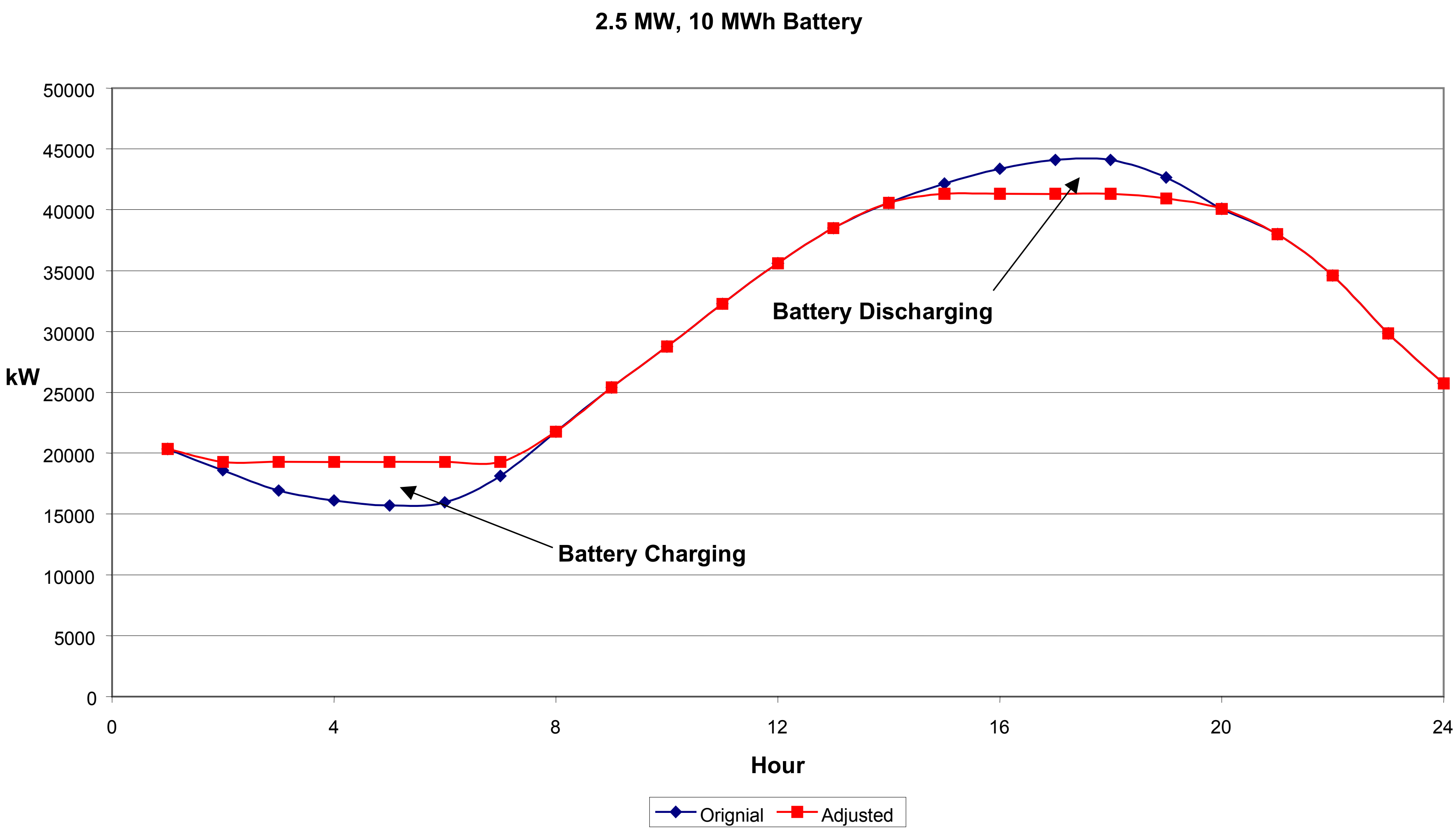


Figure 2-4: Sample Peak Shaving Operation for June 30, 1999

2.2.2.1 Busbar Energy Cost Evaluation.

One method of determining the economics of the BESS is to calculate the all-in cost of delivering electricity from the BESS to the grid and then compare that cost with possible future market conditions. To perform this analysis, Black & Veatch calculated levelized busbar energy costs for a 25 MW, 100 MWh commercial scale BESS for which vendors provided a "long-term" capital cost estimate (see Sections 3.6 and 3.7).

The busbar analysis assumes a capital cost of $36 million. It is based on a 20-year life, with 100, 182, 274, and 365 full charge/discharge cycles per year. The O&M cost is assumed to be 1 cent/kWh for each kWh of energy produced, and a recharging cost of 2.3 cents per kWh of energy consumed. Each of these are first year costs and we assumed an escalation rate of three percent per year. We assumed the present worth discount rate to be six percent, reflective of the current borrowing rate for a municipal utility. We also assumed the facility to be 100 percent debt-financed at a levelized fixed charge rate of 8.76 percent over 20 years. This levelized fixed charge rate is sufficient to repay the project loan, and to offset an assumed half percent bond issuance fee. Applying this charge rate to the total capital cost derives an annual capital cost associated with the project.

Figure 2-5 shows the levelized cost of energy versus months of operation for the 25 MW, 100 MWh system.

We note that for 100 cycles per year, the busbar cost is about 37 cents/kWh. If the battery system were operated 12 months per year (365 cycles), the amortization of capital costs over more energy (MWhs) would result in a busbar cost of 14 cents per kWh. This cost per kWh appears to be higher than current market prices, suggesting that additional capital cost reductions or sources of revenue, in addition to energy payments (e.g., ancillary services), are required for economic viability.

2.2.2.2 Ancillary Services Market.

It is possible that a battery storage facility can be used to provide ancillary services as an alternative source of revenue during those months in which the owning utility has adequate low-cost sources of generation to serve its load. Potentially, these services include:

1) **Regulation Services** – in which energy production is increased or decreased instantaneously to maintain the energy supply and demand balance in real time. This service requires a generator to be on-line and to

be synchronized. It also requires automatic generation control such that instantaneous adjustments in output can be made.

2) **Spinning Reserves** – in which a generating unit is running and has excess capacity that is ready to be dispatched, i.e. spinning, within 10 minutes of receiving a command. The unit must be able to operate for a minimum time, usually set at two hours, to be considered as a candidate for spinning reserve capacity.
3) **Non-Spinning Reserves** – in which a unit is not actually running, but is available and can come on-line in 10 minutes or less, and is capable of running for a minimum time, usually set at two hours.
4) **Other Services** – which include voltage support, replacement reserve capacity, and black start capability. These services are often procured on a long-term basis and may not be suitable for a unit seeking to occasionally participate in such markets.

Because the market for ancillary services is still developing, forecasting the market prices for such services contains at least as many unknowns as forecasting the market clearing price for energy. However, looking at the historic prices for such services in California indicates that the prices for providing such services are only marginally profitable, and would only marginally improve the economics of a battery storage unit that operates only a portion of the year. For example, during 1999 the market for providing regulation services ranged from approximately $8/MWh to $27/MWh (0.8 cents/kWh to 2.7 cents/kWh), while the market for spinning and non-spinning reserves never rose above $10/MWh (1 cent/kWh) in any month, and stayed below $5/MWh (0.5 cents/kWh) for non-spinning reserves for each month of the year.

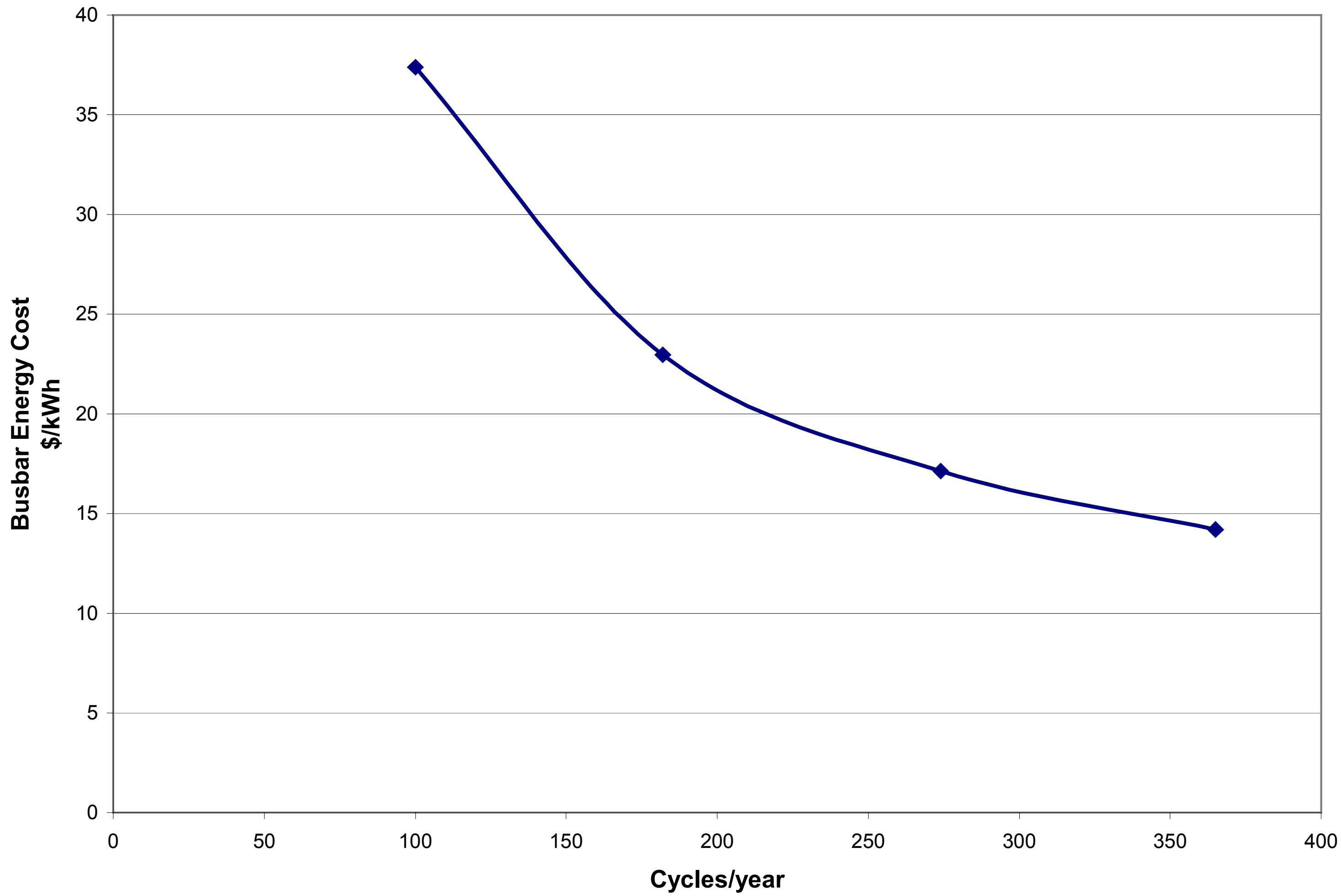


Figure 2-5: Busbar Energy Cost for Mature BESS (20-year life)

3.0 Evaluation of Advanced Battery Technologies

3.1 Purpose of Evaluation

A necessary element of the demonstration project planning was to evaluate the range of advanced battery technology options to determine which would be suitable to meet the project requirements. The technology evaluation was not intended to select a preferred technology, but rather to determine which could be included in the actual Boulder City project solicitation. This technology evaluation was performed by Gridwise Engineering, a subcontractor to Black & Veatch.

The Boulder City Project Team (Sandia National Laboratories, NEVAREST, and the city of Boulder City) had previously identified the list of candidate technologies to be included:

- Sodium Sulfur
- Vanadium Redox
- Zinc Bromine
- Regenesys®

The evaluation considered the appropriateness of the technology to the application, the electrical storage sizing requirements, the limitations imposed by the physical site (acceptable foot-print and building elevation for the energy storage facility), potential site safety issues related to the technology, and relative acquisition and operating costs for each technology.

3.2 Developer Questionnaire

A questionnaire (see Appendix A) was developed and sent to a number of advanced battery developers requesting information on their systems. The questionnaire included general questions about the technology, as well as specific questions related to the planned 2.5 MW, 10 MWh demonstration plant to be built in Boulder City.

The questionnaire asked for the following types of information.

- Project experience
- Production capabilities
- Safety
- Site layout for the demonstration plant
- Electrical configuration
- Component UL listing
- System life
- Performance

- Load following capabilities
- Maintenance requirements and costs
- Project and future capital costs

Table 3-1 provides a listing of companies from whom responses to the questionnaire were received.

Table 3-1
Vendor Response Summary

Developer	Technology	Headquarters	US Representative
NGK Insulators, Ltd.	Sodium Sulfur	Nagoya, Japan	Technology Insights San Diego, California
Powercell Corp.	Zinc Bromine	Boston, Massachusetts	Boston, Massachusetts
Sumitomo Electric Industries, Ltd.	Vanadium Redox	Osaka, Japan	Sumitomo Electric USA, Inc. Torrance, California
Vanteck (VRB) Technology Corp.	Vanadium Redox	Vancouver, Canada	(None)
ZBB Energy Corp.	Zinc Bromine	Milwaukee, Wisconsin	Milwaukee, Wisconsin

The vendor for Regensys® technology, Innogy Technology Ventures Ltd. (Ditcot, Oxfordshire, UK), was invited to participate in the evaluation. However, Innogy indicated that the project (2.5 kW, 10 MWh) was under their minimum plant size. Innogy's focus is on much larger plants, such as their two 120 MWh plants under construction in the United Kingdom and at Columbus Air Force Base in Mississippi. Therefore, Innogy's technology was not considered for this project.

Developers were informed that they will not be bound to their estimated project costs or technical characteristics for the project solicitation. However, their responses would assist the Project Team in understanding the technology attributes, costs, and approaches that might be taken in the demonstration.

3.3 Technology Readiness

Several parts of the Questionnaire were intended to determine whether a vendor's technologies are developed to the stage that a project of this size would be technically feasible. All of the technologies have been tested in grid-connected field demonstrations, and sodium sulfur stood out because it had the most grid-connected field demonstrations. Likewise, sodium sulfur has significantly larger production capabilities in comparison to the flow batteries, both in production capacity (160 MWh per year) and in actual production over the past year (50 MWh). There are more than 30 relevant storage projects in Japan based on the sodium sulfur technology, the largest of which is a 6 MW/48 MWh system, several times the anticipated size of the Boulder City project (see Figure 3-1).

Figure 3-1: 6MW/48MWh Sodium Sulfur Battery
(Ohito substation, Tokyo Electric Power Co.).

None of the technologies has reached full commercial status, complete with certifications from Underwriters Laboratories (UL). One of the zinc-bromine developers indicated that UL certification would be completed for the battery component in time for this project; however, we believe this might be optimistic. It is likely that only the power electronics, controls, and other BOS components will have UL certification. Note that UL certification is not a requirement for this utility-hosted project.

A summary of the technologies, as characterized by readiness, is provided in Table 3-2. While sodium sulfur is clearly at a more advanced stage in field experience and production capabilities, all three technologies appear to be sufficiently developed to be included in the Boulder City project.

Table 3-2 Technology Readiness			
	Sodium Sulfur	**Vanadium Redox**	**Zinc Bromine**
Field Experience	Over 30 projects ranging from 25 kW to 6 MW. Largest commercial installation is 48 MWh.	Several projects, ranging from 100 kW to 3 MW (pulse power rating). Largest commercial installation is 1.5 MWh.	Several projects, from 50 kW to 250 kW. Largest commercial installation is 400 kWh.
Annual Production Capacity	160 MWh	30 MWh	40 to 70 MWh
Actual Production, Last 12 months	50 MWh	10 MWh	4.5 MWh
UL Listing	Expected to have UL report by early 2002. Electronics would be UL listed.	Electronics only	Electronics and possibly battery

3.4 Site Layout and Footprint

One of the constraints of the project is the available land (approximately 1.25 acres) and municipal height restriction (25 feet). Therefore, it was necessary to determine whether the technologies would be able to meet these limits. The system would be comprised of the battery, power electronics, cooling systems, transformation to the utility 12 kV distribution voltage, a parking lot, and a small Visitor's Center. All of this must fit into the available property boundaries.

Responses indicated that, while there is a wide range in reported footprint, all of the technologies would be acceptable. None of the technologies would be eliminated on the basis of footprint.

Table 3-3 Site Layout and Footprint			
	Sodium Sulfur	**Vanadium Redox**	**Zinc Bromine**
Structure	Outdoor rated battery enclosures and PCS enclosures	Building enclosure	Building enclosure
Footprint	About 5,000 ft^2	12,000 to 17,000 ft^2	5,000 to 7,000 ft^2

In some cases, we made adjustments to the reported footprint values, because some responses were not based on the same assumptions. For example, some responses did not include a step-up transformer, so additional square footage was included to account for an outdoor pad-mounted 2.5 MVA transformer. We made such estimates using the available component size and modularity data, although the developers themselves could have made a much better estimate through a more detailed design effort.

Footprints reported in the table do not include the parking lot and Visitor's Center. A sample layout for the zinc bromine technology is shown in Figure 3-2. This layout includes an outdoor, pad-mounted transformer, a control room and supervisory control and data acquisition (SCADA) interface, a staging area for installation and maintenance, power conversion system (PCS) and direct current (DC) switchgear cabinets, chillers for cooling the electrolyte, and the DC battery strings.

Systems were also characterized by the enclosure type. The sodium sulfur modules are housed in outdoor enclosures, while the flow batteries require a separate building enclosure, constructed to house stacks, pumps, and electrolyte tanks.

3.5 Life and Performance

We asked Developers to provide estimates of system life, assuming that the batteries were dispatched 100 days per year to discharge 10 MWh to the grid. Lifetimes ranged from seven to 20 years.

In some cases, developers reported that some components, such as reactor stacks, would have lifetimes less than other components like power conversion equipment, tanks, plumbing, etc. However, most developers recommended replacement of the entire system at the end of the reported period, regardless of the small amount of residual value.

Vendors reported efficiencies that assumed a constant 2 MW discharge rate, a 1 MW charge rate, and included all losses associated with AC voltage transformation and bi-directional AC/DC power conversion. Values ranged from 65-80 percent. However, it is unlikely that 80 percent would be achieved. Assuming transformer losses of approximately two percent (incurred twice - during both charging and discharging), and

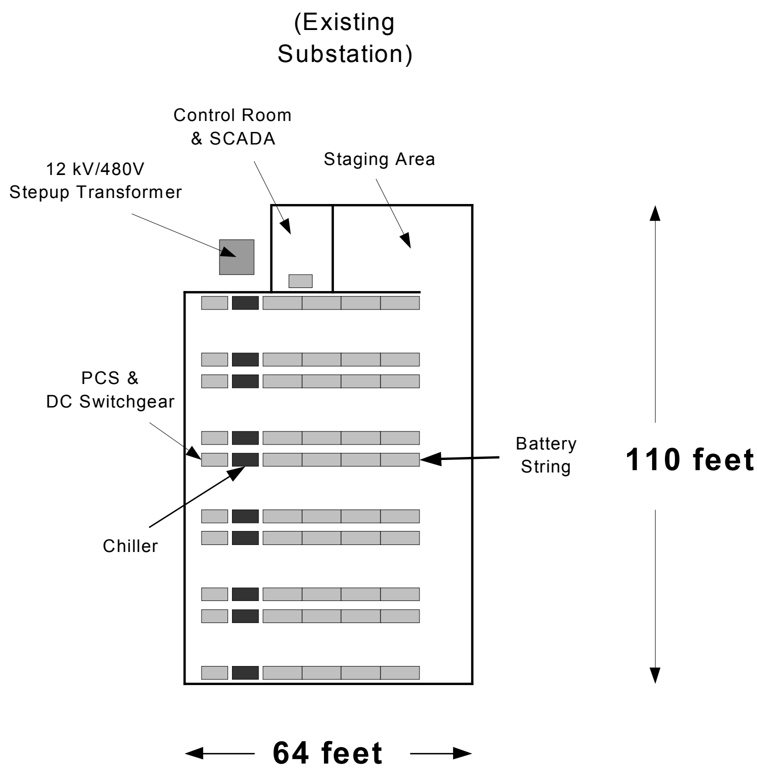


Figure 3-2: Sample Zinc Bromine Site Layout.

power conversion losses of four percent (also incurred twice), the non-battery energy losses would be about 11.5 percent. A BESS system with 80 percent AC/AC efficiency must have a battery round-trip energy efficiency of 90 percent, which is unlikely. Table 3-4 reflects reported life and performance data.

Table 3-4
Life and Performance

	Sodium Sulfur	Vanadium Redox	Zinc Bromine
Life	15 years	7 to 15 years	10 to 20 years
Efficiency (AC to AC)	72 percent	70 to 80 percent	65 to 70 percent

3.5 Operations and Maintenance

Each of the developers indicated that its systems would be operated unattended, and in some cases the systems would be monitored remotely. Detailed maintenance requirements are known for the sodium sulfur technology, given the higher level of relative field experience. For the flow batteries, the specific maintenance requirements (and intervals) are not well established, and the cost estimates for O&M ranged from $30,000 to $150,000 per year.

Maintenance contracts would generally be offered by the developers to ensure that the systems are kept in good condition.

Table 3-5
O&M and Capital Costs

	Sodium Sulfur	Vanadium Redox	Zinc Bromine
Operators on-site	None	None	None
Required maintenance	Remote monitoring. Three-year inspections include retorquing terminals, collecting/analyzing OCV data, sensor calibration, system testing.	Quarterly or annual maintenance. Periodic parts replacement (pumps and fans every 5 to 10 years).	Remote monitoring, annual inspections. Specific maintenance items still to be developed.
O&M Cost	$32.5k per year	$50k per year	$30-150k per year

A sample vanadium redox maintenance schedule is shown in Figure 3-3. In this case, annual inspections are performed, and periodic replacement of sensors, pumps, fans, relays, and other parts is required.

△ Inspection ○ Exchange of Parts										
Year after operation	1	2	3	4	5	6	7	8	9	10
Periodical inspection	△	△	△	△	△	△	△	△	△	△
Calibration of sensor Check of protection function Check of appearance and insulation	Once a year for 10 days									
Replacement of parts (periodical inspection)										
Pump					○					○
Fan					○					○
Electric parts (condenser, etc.)								○		
Sensor			○			○			○	
Relay, Fuse, etc.							○			
Rough Cost	Ave: Approx. 20 US$/kW/year. (2500 kW system base)									

Figure 3-3: Sample Vanadium Redox Maintenance Schedule.

3.6 Capital Costs

We requested that developers provide capital costs under three scenarios:

1. Boulder City Demonstration Project: A 2.5 MW, 10 MWh system commissioned in April 2003. This estimate could be used for budgeting purposes.
2. Near-Term 100 MWh System: This would be the cost of a system after about 50 MWh of other BESS projects were on-line.
3. Long-Term 100 MWh System: This would be the long-term cost targets for the respective technologies.

They were instructed to make their cost estimates using the assumptions in Table 3-6.

Table 3-6 Cost Estimate Assumptions	
Requirements/ Assumptions	2.5 MW (AC) 10 MWh (AC, delivered to grid when discharged) Contract award: April 2002 Commissioning: April 2003 Attractive building or container for residential area.
Estimate to Include	Battery and Auxiliaries PCS AC Switchgear Transformation to 12 kV Utility Protection Structures/Containers Control & Monitoring System Design and Engineering Construction & Installation Startup Testing/Commissioning Spare parts Shipping All taxes, duties, licenses Bonds & insurance costs
Estimate to Exclude	Land Grading Fencing Access road Parking lot Visitor's display Landscaping Financing costs to owner

Table 3-7 contains the developer estimates. The costs for the 2.5 MW, 10 MWh Boulder City Project are within a reasonably close range, from a low of $8M (zinc bromine) to a high of $12M (sodium sulfur). The long-term costs vary by a factor of almost three.

Table 3-7 BESS EPC Costs			
	Sodium Sulfur	**Vanadium Redox**	**Zinc Bromine**
2.5 MW, 10 MWh	$12 Million	$10.9 to $11 Million	$5.8 to 8 Million
100 MWh (Near Term)	$35 Million	N/A	$38 Million
100 MWh (Long Term)	$30 Million	$66 to 83 Million	$32 to $50 Million

3.7 Conclusions

Of the original four technologies considered for the Boulder City Project, three appear to meet the basic requirements: sodium sulfur, vanadium redox, and zinc bromine. The Regenesys® technology is intended for larger systems and would not be considered for a 2.5MW/10 MWh installation.

All three technologies appear to have adequate field experience, although they differ significantly on the depth of experience. Sodium sulfur has a number of multi-megawatt grid-connected projects in Japan, and is by far the most experienced and has the highest production capacity.

All of the technologies can meet the footprint and height restrictions without difficulty. However, sodium sulfur and zinc bromine have a distinct advantage in footprint.

Lifetimes will be in the 10-15 year time frame, and AC to AC round-trip efficiencies are expected to be in the low 70 percent range.

All of the technologies are capable of unattended operation, and the maintenance costs will be in the range of $30,000 to $150,000 per year, with four of the five responses in the $30,000 to $50,000 per year range. The specific maintenance requirements are still under development for some of the flow technologies.

Capital costs for the Boulder City project range from a low of about $5.8M (zinc bromine) to a high of about $12M (sodium sulfur). The sodium sulfur estimate and the lowest zinc bromine estimate indicate similar low long term capital cost targets of around $30M for a 100 MWh system ($300/kWh).

4.0 Conceptual Design of Boulder City Demonstration Unit

4.1 Site Layout

We developed a site layout using specifications received from vendor surveys and peripheral items developed for the demonstration site. The layout shows the relative locations of the different components (e.g. battery system, parking lot, Visitor's Center, substation). Figure 4-1 shows an aerial view of the site. Figure 4-2 shows a wide-angle view of the site, including the adjacent Hemenway Substation. A footprint of the proposed site can be seen in Figure 4-3. The footprint references two of the technology types, Sodium Sulfur and Zinc Bromine. These were selected for the layout to give relative sizes of two different structure types, the stand-alone nature of the Sodium Sulfur and the enclosed building of the Zinc Bromine. These two structure types were also used in the computer renditions of the demonstration site. The renditions can be seen in Figures 4-2 through 4-7. (See also the artist's renditions shown previously in Figures 1-2 and 1-3).

4.2 Substation Upgrades

The battery storage project would be located adjacent to the 12.47 kV Hemenway substation, (Substation Number 6). This substation would serve as the connection point for the proposed battery storage system to charge the batteries during off-peak periods and receive AC power from the battery storage inverter system when market prices and loads justify its usage.

The existing substation has two 69-12.47 kV substation transformers fed from two separate 69 kV transmission lines. The 12 kV side of each transformer feeds a radial bus. Both the 69 kV feed to the transformers and the 12 kV side have disconnects configured in a main-tie-main arrangement. This would allow each 69 kV line to feed one or both transformers, and each transformer could feed one or both of the 12 kV busses. Figure 4-8 is a simplified, electrical one-line drawing of the substation, the interconnect, and the BESS.

Figure 4-1: Hemenway Substation during construction, aerial view.

Figure 4-2: Hemenway Substation, panoramic view.

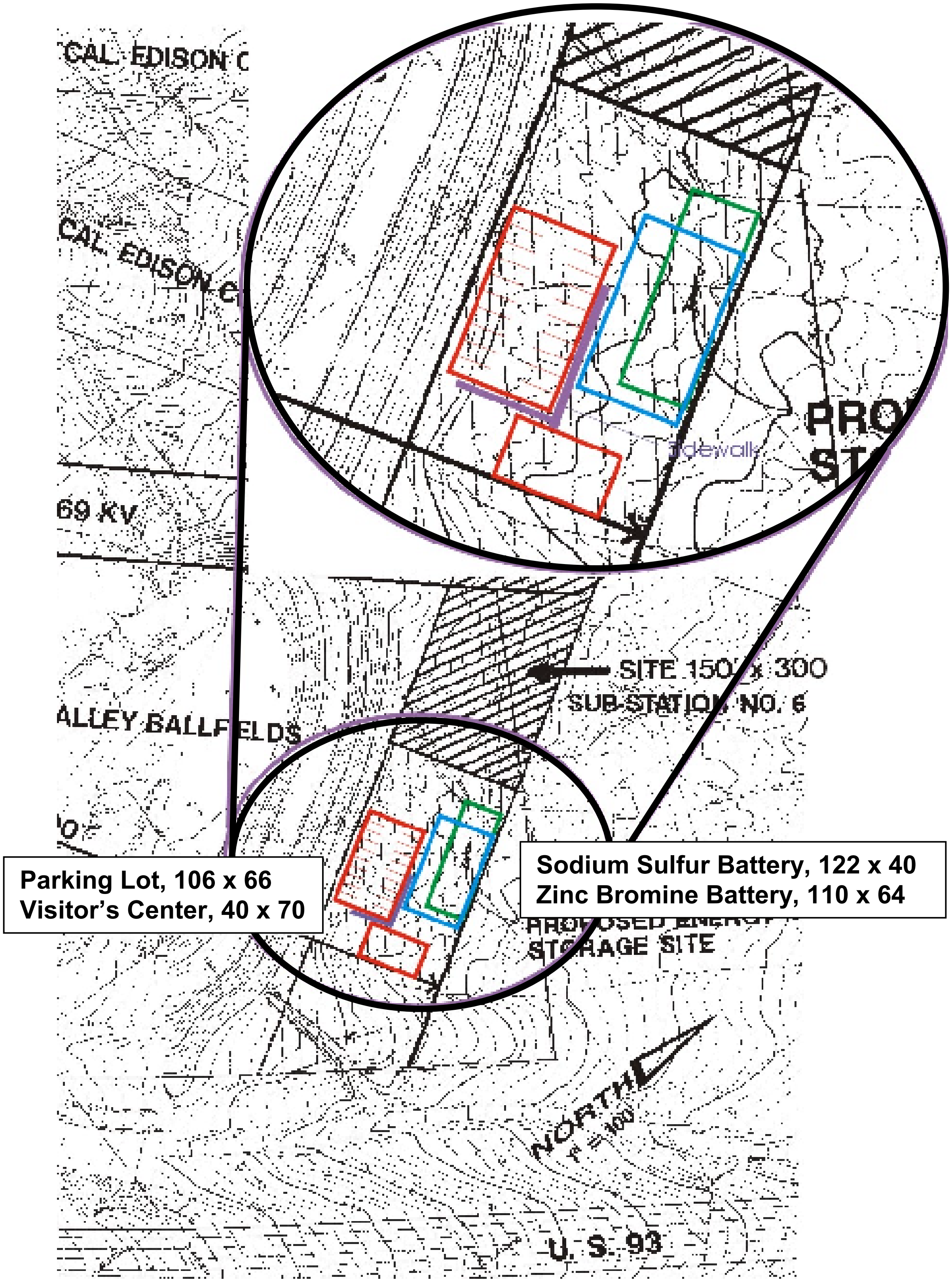


Figure 4-3: Site Footprint.

Figure 4-4: Computer Rendering From South: Self-Enclosed BESS

Figure 4-5: Computer Rendering From South: BESS Enclosed in Building

Figure 4-6: Computer Rendering From West: Self-Enclosed BESS

Figure 4-7: Computer Rendering From West: — BESS Enclosed in Building.

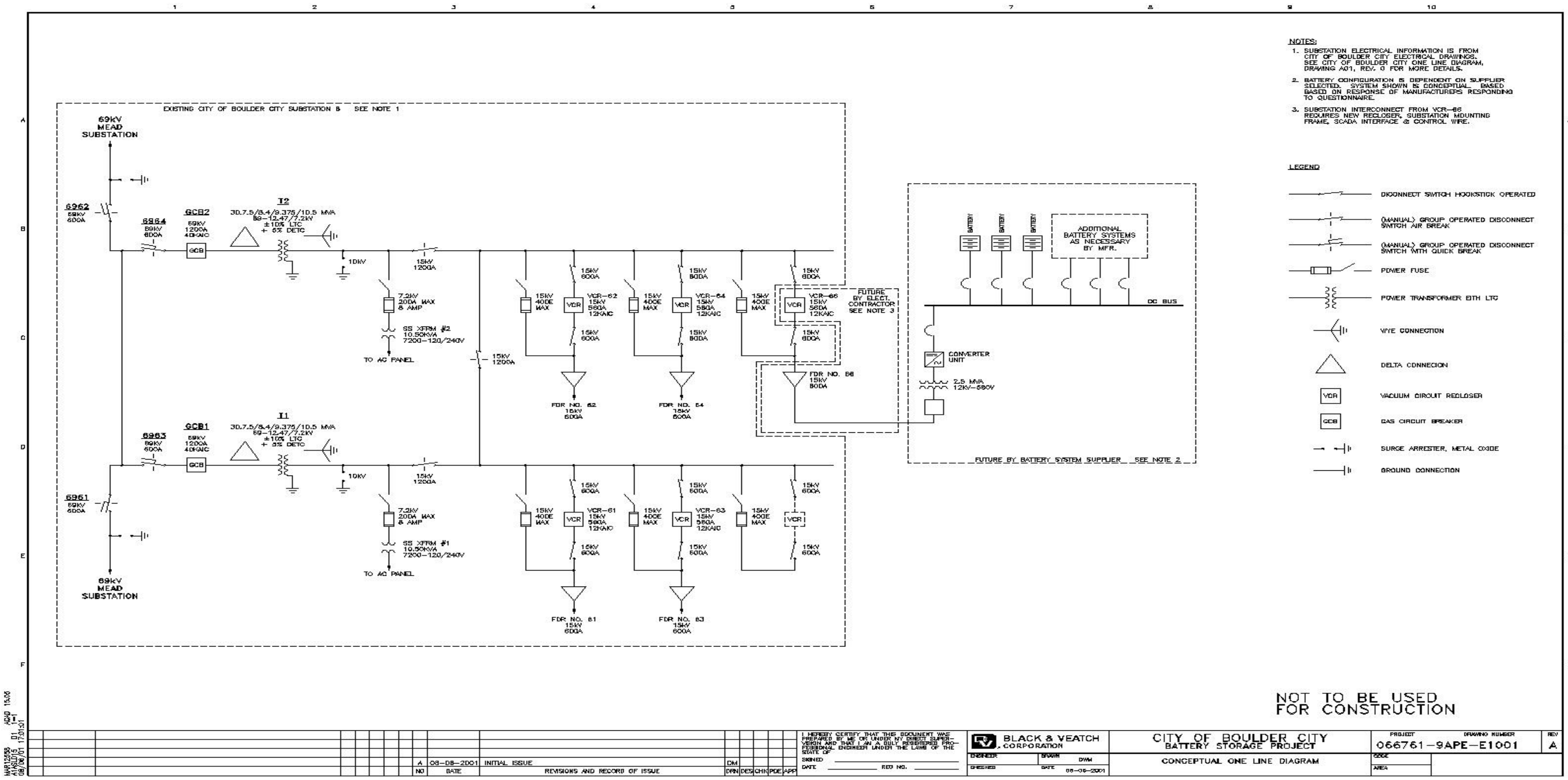


Figure 4-8: Electrical One line Diagram.

4.2.1 Vacuum Circuit Recloser Position

The City of Boulder City recommended that Black & Veatch use the existing, but unequipped, spare vacuum circuit recloser position on the 12 kV bus fed from transformer bank T2. We expect that this position will be identified as VCR-66. This substation bay was constructed as a "future" bay, with relatively minimal equipment required to make it a functional bus connection point. It currently contains two isolating disconnects, to be used for isolating a future vacuum circuit recloser, and a fused disconnect switch to bypass the recloser and keep the feeder energized during recloser maintenance.

Upgrading the spare 12 kV bay would be accomplished by using the same equipment and construction techniques in the other bays adjacent to VCR-66. Discussions with the City of Boulder City's electrical engineering department have identified the following major equipment necessary for this improvement:

- Cooper Power KNOVA Form C Vacuum Circuit Recloser catalog number KNOVA27A11
- Electronic controller, catalog number KME4C11122
- Substation mounting frame
- 200 feet of control cable
- 450 feet of 15kV, 1/0 shielded cable (150 feet/phase)

4.2.2 SCADA/Protective Relaying Equipment

City engineering representatives have informed Black & Veatch that adequate Remote Terminal Unit (RTU) hardware is available for interfacing the new vacuum circuit recloser control into their existing Supervisory Control and Data Acquisition (SCADA) system. The conceptual design includes a small contingency for additional RTU cards and installation in the event they are required.

The existing substation uses Schweitzer Engineering Labs (SEL) protective relays for distribution feeder protection. The upgrade would use an SEL overcurrent and reclosing relay, plus an Electro Switch Series 24 Control Switch and Lockout Relay for feeder protection and local control. The City has requested that the protection and control be located inside the control building in a protective relay panel that is installed and dedicated for this purpose.

4.2.3 Conduit Connections

A six-inch schedule 80 PVC conduit runs under the south wall from VCR-66, transitioning through an underground vault into a five-inch conduit, and continues outh towards the Hemenway Channel in one of two unprotected, direct buried-duct banks. This conduit is adequate for the cable quantity and type required to connect the battery system to the substation.

All conduits, and specifically those available for connecting VCR-66 to the 12 kV side of the battery system transformer, are easily accessible to tap into and reroute as necessary. Most of these existing conduits would likely pass under a portion, or possibly all, of the new Visitor's Center and parking lot, depending on the site design and arrangement. Consequently, portions of these duct banks might be subjected to soil settling or additional loading from the Visitor's Center.

Although it would be preferable for all conduits to be routed in a concrete-encased duct bank and/or rerouted around the Visitor's Center to avoid potential loading damage, this might be relatively expensive, and possibly not even necessary, depending on the final design. The conceptual design includes pilings and concrete support to be incorporated into the building foundation and lot design for protecting the conduit and cable from potential settling and loading.

All potential battery manufacturers are expected to provide a 2,500 kVA transformer with a 12 kV high voltage winding and a low voltage rating, as required for their specific design needs. This transformer would be connected to new 12 kV cable via the vendor supplied switchgear, using standard distribution materials and techniques approved and used in the Boulder City distribution system.

4.3 Visitor's Center

Figure 4-9 shows a floor plan and side views of a 2,800 square foot Visitor's Center. The Visitor's Center includes an exhibit hall, attendant's office, and rest rooms. We anticipate that the Visitor's Center would house exhibits on the Boulder City BESS, battery energy storage technologies in general, and on renewable energy technologies and demonstration projects. The Hemenway Substation is located adjacent to US Highway 93, which is the route from Las Vegas to Hoover Dam. According to estimations, more than 15 million tourists per year drive by the site. Therefore, the proposed site provides a unique potential to educate large numbers of US citizens and international visitors on energy storage and renewable energy technologies.

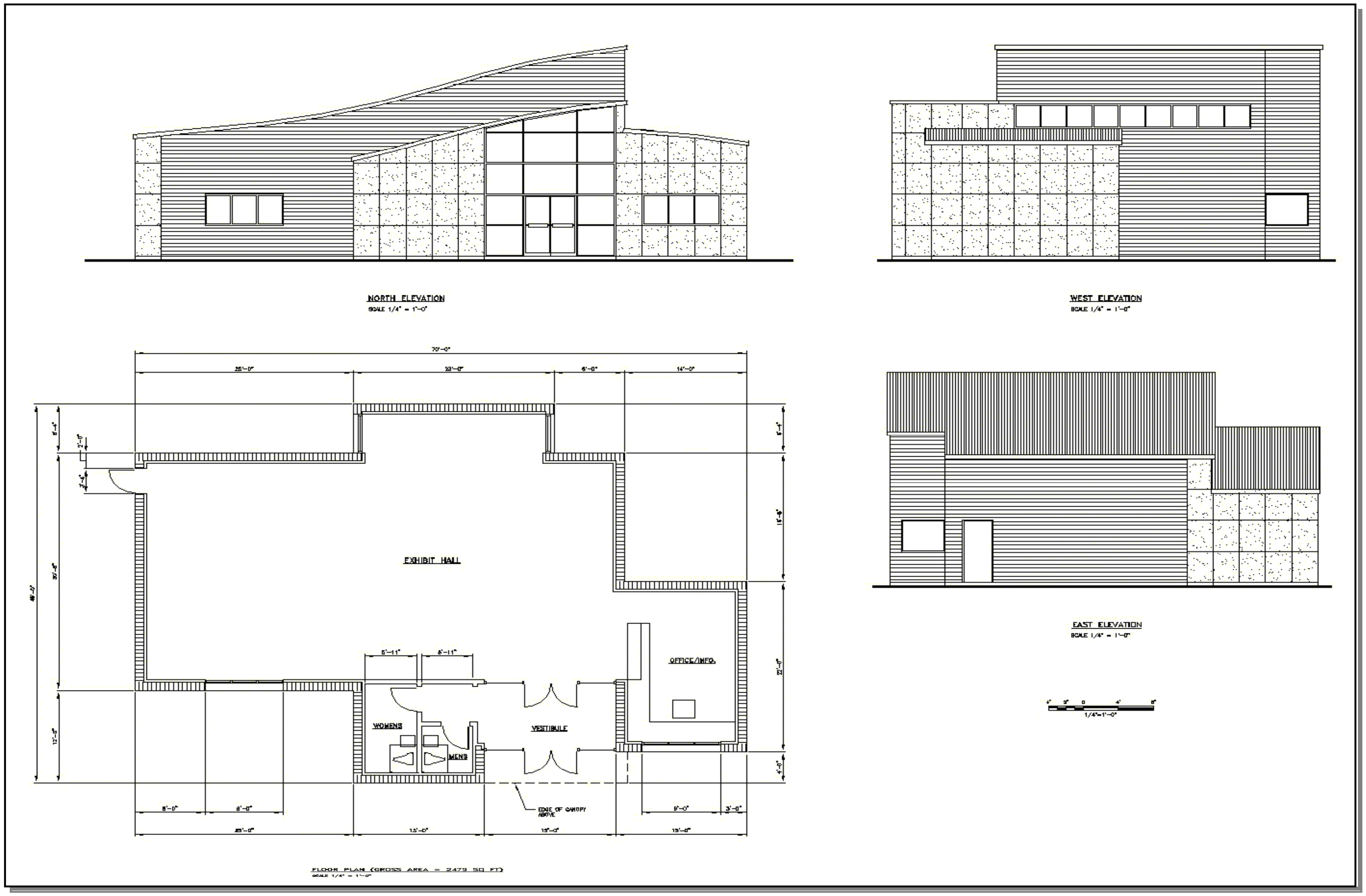


Figure 4-9: Visitor's Center Layout.

4.4 Cost Estimate

A turnkey cost estimate was developed for the different battery technologies. The estimate is included in Table 4-6.

Table 4-6
BESS Demonstration Unit Capital Costs
(Thousands of Year 2001 US$)

	Sodium Sulfur	**Vanadium Redox**	**Zinc Bromine**
EPC Battery System Cost	12,000	11,000	5,800 to 8,000
Electrical Upgrade	65	65	65
Visitor's Center	275	275	275
Parking Lot	121	121	121
Engineering	300	300	300
Construction Management	150	150	150
Contingency	632	612	323 to 432
Total	13,543	12,523	7,034 to 9,343

5.0 Economics of the Demonstration Project to Boulder City

We estimated the net benefits of the project for Boulder City as a net present worth of the difference between the City's project benefits and costs. Project costs comprise the City's allocation of capital-related costs, the cost to operate and maintain the facility, and the cost to recharge the batteries during off-peak periods. Project benefits comprise the reduced purchases of energy and capacity that are attributable to the battery storage project. Specific credit for ancillary services has not been included because, at present, costs to the city for ancillary services are embedded in the energy and capacity payments.

5.1 Boulder City Project Costs

The current expectation is that the fixed-cost contribution of Boulder City to the project will consist of the value of the site for the facility and project support from existing personnel. These are "sunk" costs in that the site will be at an existing substation already owned by Boulder City and because the project support provided by City utility personnel will not require additional hires. In the Boulder City Project financial model, no capital-related costs are assigned to Boulder City.

The battery storage unit will have variable operations and maintenance (O&M) costs associated with it. On the basis of input from the technology vendors, we have estimated these costs to be $35,000 per year, escalated at three percent per year, the general inflation rate assumed in the study. The other cost category is the cost to recharge the batteries during off-peak periods. Charging costs are at 2.3 cents per kWh, with a charge/discharge efficiency of 70 percent.

5.2 Boulder City Project Benefits

The project benefits include the reduced energy and capacity purchases by Boulder City that result from discharging the battery during peak periods. Therefore, it is necessary to project the avoided costs that will be attributable to the project.

Boulder City has a low-cost power supply, largely attributable to its hydroelectric energy resources. Table 5-1 indicates the power resources and the associated costs available to Boulder City. The City serves its load by allocating these resources on a merit order, or economic dispatch basis. This means that the lowest cost resources are dispatched first, followed by the next lowest cost, and so forth, until the system load is served.

Table 5-1
Boulder City Power Resources

Resource	Capacity (MW)	Capacity Price ($/kW-mo.)	Energy (MWh)	Energy Price (cents/kWh)	Contract Expiration
Hoover Dam (WAPA)[a]					
Schedule A	20	0.99	80,000	0.754	2017
Schedule B	8.5	0.99	17,870	0.754	2017
SLCA (CRC)[b]					
Summer	5.953	3.44	13,149	0.81	2019
Winter	5.953	3.44	17,419	0.81	2019
Nevada Power Co.					
Amendment 1	Not limited	5.02	Not limited	2.3	
Schedule D			As needed	NPC Marginal Cost[c]	
Reliant Energy	10		Open	5 to 9	2022

Source: City of Boulder City
Notes:
[a] Western Area Power Administration
[b] Salt Lake City Area, Colorado River Commission
[c] Averaged 8.5 cents/kWh in 2000

The lowest cost resources are those provided by the Western Area Power Administration (WAPA) and the Salt Lake City Area Integrated Projects (SLCA/IP), which comes through the Colorado River Commission (CRC). This results in the Schedule A and B WAPA allocations being dispatched first, followed by the SLCA/IP (CRC) capacity. Beyond the City's hydroelectric allocations, purchases are made through the City's Amendment 1 purchases from Nevada Power Company (NPC), with the requirement that the capacity must be reserved a month in advance and through Schedule D purchases. Purchases from Reliant are also possible, if scheduled a year in advance.

The ability of Boulder City to receive its full hydroelectric allocation is dependent on water flow resources, including yearly rainfall and snowfall. These hydroelectric resources were sufficient to meet the City's full load for seven months in 1999 and for four months in 2000. Purchases from NPC were required to serve the City's load in the remainder of the months. In 1999, purchases from NPC occurred in June through October, and May through December in 2000.

When purchases from NPC are made through Amendment 1, costs are relatively low. However, there is a capacity charge element that can result in high incremental costs. NPC Schedule D purchases are on an as-needed basis, and are at the NPC marginal cost. The costs can be substantially higher than Boulder City's other resources because the rate for Schedule D energy is market-based. Thus, reflective of the region's high natural gas prices and lower capacity margins in 2000, the monthly average price associated with the Schedule D purchases ranged from a low of 5.9 cents/kWh in September 2000 to a high of 18.8 cents/kWh in December 2000. The weighted average cost of Schedule D purchases was 8.5 cents/kWh in 2000. It is primarily the Schedule D purchases that the battery energy storage system displaces.

5.3 The Economics of Boulder City's Participation in the Demonstration Project

Based on the cost and benefit categories listed above, a project financial model was constructed to reflect the economics of the demonstration project from the perspective of Boulder City. The input assumptions and results are described in this section.

The financial model assigns no capital cost of the demonstration project to Boulder City, based on the expected cost allocation. The costs to Boulder City associated with the project are limited to the facility's operation and maintenance cost of $35,000 per year, escalated at three percent, and off-peak recharging costs assumed to be 2.3 cents/kWh, escalated at four percent per year. The lifetime basis for the vendor estimates was 100 cycles per year. Our base case modeling is, therefore, 15 years at 100 cycles per year.

We note that the year 2000 profile of purchases from NPC could probably accommodate full battery cycling daily for six months of the year. The average monthly output from the battery energy storage system would be about 300 MWh. In the year 2000, actual monthly Amendment D purchases from NPC varied from 649 MWh to 3,461 MWh, with a total purchase for the year (six months) of 12,215 MWh. Therefore, it is reasonable to expect that the battery energy storage system could displace Schedule D purchases for the full 300 MWh during each of the six months. From a Boulder City system perspective, therefore, it is likely that 180 cycles per year could be justified. However, operation of the BESS at 180 cycles per year would likely shorten the lifetime to less than ten years.

The cost of the Schedule D purchases in the first year is assumed to be 9.98 cents/kWh, which is the average Schedule D purchase price in 2000, escalated to 2004 at four percent per year. This avoided-cost rate continues to be escalated at four percent during the 15 year pro-forma evaluation period. Other input assumptions include a three percent general inflation rate and a six percent present worth discount rate for Boulder City.

The results of the financial model from the perspective of Boulder City show that the project has a net present value, after-tax cash flow, of $424,000. This means that, on a present value basis, Boulder City ratepayers would realize a $424,000 net benefit under the assumptions of the study. This benefit arises because the O&M costs and recharging costs incurred by the City would be less than the benefit of displacing the more costly Schedule D purchases. The benefits-to-cost ratio is 1.52:1. This ratio is calculated as the present value of the avoided Schedule D purchases divided by the present value of the O&M and recharging costs for Boulder City. The 1.51:1 ratio indicates that the project will be beneficial to Boulder City ratepayers under the Schedule D price assumptions used.

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Appendix A. Developer Questionnaire

Boulder City Storage Project
Battery Developer Questionnaire

Project Background

Boulder City, Nevada (pop. 15,000) is a small "bedroom" community located approximately 20 miles southeast of Las Vegas and about five miles from Hoover Dam. The City owns and operates its own municipal electric utility, serving a mix of residential and light commercial loads. In 1999, the City purchased 153,000 MWh of wholesale power and experienced a peak demand of 45 MW. The system peaks always occur in the summer afternoons, due to the high air conditioning loads.

The City receives the bulk of its power through preference allocation from hydroelectric plants on the Colorado River, including Hoover Dam and Glen Canyon Dam. Wholesale suppliers include Western Area Power Administration (WAPA), the Colorado River Commission (CRC), and the Salt Lake City Area Integrated Projects (SLCA/IP). Boulder City is in the Nevada Power Company Load Control Area. Nevada Power handles the dispatching of Boulder City's power supply resources.

The amount of power the City receives from these resources is limited, and allocations are contingent upon uncertain water flows through the dams. Any needs above these allocations must be satisfied by purchasing higher cost power on the spot market. The capacity and energy requirements change on a regular basis, depending on river flows and operational constraints at the dams. Summer energy shortfalls of 5,000 to 10,000 MWh per month and capacity shortfalls between 4 MW and 10 MW are typical.

Minimal river flows are maintained during the light load, nighttime hours. An energy storage device could capture this energy, then discharge it back into the City's distribution during peak hours. This would reduce transmission-level demand charges and offset high cost energy. As the demand charges represent the cost of transmission access and ancillary services, the storage device would, in effect, be serving multiple applications and providing multiple benefits.

Nevada Renewable Energy Storage Technology (NEVEREST) Research, a non-profit corporation formed to promote energy storage and renewable energy, has developed a demonstration project concept and is currently seeking funding from various public and private sources. Sandia National Laboratories is supporting the project by providing technical oversight. Sandia has commissioned a preliminary study, which includes an analysis of the seasonal load profiles, an evaluation of advanced battery technologies, a pre-conceptual design, an initial cost estimate, and an economic evaluation. Black and Veatch (prime contractor) and Gridwise Engineering Company (subcontractor) are conducting the study.

The demonstration project is intended to validate the use of advanced battery technologies, scaled down to a nominal size of approximately 2.5 MW, 10 MWh. The turnkey-project solicitation is planned to be released in 2002, in order to have the system installed and commissioned approximately mid-year 2003. Several advanced battery technologies, including Sodium Sulfur, Vanadium Redox, Zinc Bromine, and Regenesys® are being considered and are included in the preliminary study.

The project will also be an attractive technology showcase for industry participants and the general public. A site in the Hemenway Valley, owned by Boulder City and overlooking Lake Mead, has been selected as a desirable location for this project. The site is surrounded by a number of expensive homes, the closest of which is approximately 1000 feet away, and is adjacent to an existing softball field and a new 12 kV distribution substation. The site would be landscaped so that the facility would blend into the natural surroundings and would include a small visitor's information display. It is visible and accessible from U.S. Highway 93, approximately five miles from Hoover Dam. The site, subject to the Boulder City height restriction of 25 feet, is approximately 1.25 acres in size, classified as seismic Zone 2, and zoned GP (Government Park), in which electrical distribution facilities are allowed.

Questionnaire

Please provide responses to the following questions via email by Wednesday, June 27 (California time). Only include information that is of a non-proprietary nature that can be included in public reports.

Technology

Technical Papers and Photos. Provide, in electronic form, general materials describing your technology, such as technical papers. Include some high-resolution photographs, if available.

Experience. Provide a list of recent relevant projects, including descriptions and ratings. In particular, include information about systems that have been fielded on a commercial basis. What is the largest system built to date?

Production Capabilities. What is your current production capacity of the battery technology (MWh/year)? What was the actual production in 2000 (MWh)?

Safety. Describe any hazardous (such as corrosive or highly flammable) chemicals found in your system and the methods used to ensure safety. Describe any safety practices that you recommend, other than electrical safety. Also, describe the method used to contain electrolyte internal and external to the DC battery.

Power curve. Provide current and voltage specifications for the underlying DC battery module or cell, including voltage window and average discharge voltage. Provide a curve showing energy output (kWh) versus continuous (non-pulse) power output (kW).

2.5, 10 MWh Demonstration Project

Site Layout. Given the Boulder City height restriction of 25 feet, describe conceptually how the system would be configured, e.g., how would standard modules be configured in outdoor structures. Give rough dimensions of major components. Estimate total footprint of the system (length x width), including the battery, cooling system, power conversion system, switchgear, step up transformer, and all other balance-of-system equipment. Do NOT include access roads, parking, or visitors information display in your estimate. If there are any siting characteristics that we would want to know, such as standard containers that you would likely use, describe these. It is not necessary to provide drawings.

Configuration. Describe the basic electrical layout of the system that you would likely use for the demonstration system, such as how you would aggregate DC modules, inverter ratings, etc. It is not necessary to provide drawings.

UL Listing. Describe the components of the system that would not be UL listed. Provide other relevant certification information.

Life. What would be the approximate life of the system, assuming that it were cycled to discharge 10 MWh of energy, 100 days per year? Are there are certain components (such as reactor stacks) that could be replaced at end-of-life without replacing the entire system? If so, what would be the life of these components and the approximate percentage of total AC system cost?

Efficiency. What is the round-trip efficiency, including AC transformer and power conversion losses, of the system? Assume constant power discharge of 2 MW and constant power charge of 1 MW.

Load Following. The preferred operating strategy would be to dynamically vary the output over the duration of the 4-6 hour peak period, such that power imports to Boulder City would not exceed a preset threshold value. The maximum output would be at the peak hour, and would be limited by the 2.5 MW power conversion system rating. This would require that real time load signals be provided via the utility SCADA system to the BESS control system. Would the BESS capable of this type of control? What would be the minimum power level?

O&M. Considering the whole AC system, is it necessary to have an operator on-site on a full-time or part-time basis? What maintenance and inspection activities are required on a monthly basis? Annual basis? Other schedule? What procedures and parts replacements would be required to ensure warranty compliance? Would you provide a service contract to perform this maintenance? Whether provided by you or performed by the owner, what would be an approximate cost to the utility for this service?

Demonstration Project Capital Costs. Provide an estimate of the total capital cost of the demonstration project. This estimate is not a quote and is not binding in any way. The estimate should assume that the manufacturer does not provide any cost sharing.

Requirements/ Assumptions	2.5 MW (AC) 10 MWh (AC, delivered to grid when discharged) Contract award: April 2002 Commissioning: April 2003 Attractive building or container for residential area.
Include	Battery and Auxiliaries PCS AC Switchgear Transformation to 12 kV Utility Protection Structures/Containers Control & Monitoring System Design and Engineering Construction & Installation Startup Testing/Commissioning Spare parts Shipping All taxes, duties, licenses Bonds & insurance costs
Exclude	Land Grading Fencing Access road Parking lot Visitor's display Landscaping Financing costs to owner

Projected Capital Costs.

Assume that over the next few years you were to install another 50 MWh of utility BESS systems. After that time, using the same assumptions as above, what would be the approximate cost of a scaled up 25 MW, 100 MWh system (in 2001 dollars)?

What do you believe is your long-term projected cost of a 25 MW, 100 MWh system (in 2001dollars)?