Cost and Performance Trajectories for Power Generation Technologies

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ABSTRACT

National Renewable Energy Laboratory (NREL) in 2009 to provide the power generating technology cost and performance estimates and early 2010 and therefore reflect the environment. Many factors drive the cost and price of a given technology. Mature technologies generally have a smaller band of uncertainty around their costs because demand/supply is more stable and technology variations are fewer. For mature plants, the primary uncertainty is associated with the owner-defined scope that is required to implement the technology and with the site-specific variable costs. It is not possible to reasonably forecast whether future commodity prices will increase, decrease or remain same. Although the costs in 2009 are much higher than earlier in the decade, for modeling purposes, the cost presented here do not anticipate dramatic increases or decreases in basic commodity prices through 2050. Many factors influence rates of deployment and resulting cost reduction and in contrast to learning curves, a linear improvement was modeled to the extent possible.

Key Words: *NREL, Power generation technologies and environment etc.*

1. INTRODUCTION

Black and Veatch contracted with the National Renewable Energy Laboratory (NREL) in 2009 to provide the power generating technology cost and performance estimates that are described in this paper. These are site –specific items and owner specific items. Mature power plant costs are generally expected to follow the overall general inflation rate over the long term. Over the last ten years, there has been doubling in the nominal cost of all power generation technologies and an even steeper increase in coal and nuclear because the price of commodities such as iron, steel, concrete, copper, nickel, zinc, and aluminum have risen at a rate much greater than general inflation, construction cost peak in 2009 for all types of new power plants. Even the cost of engineers and constructors has increased faster than general inflation has with the recent economic recession, there has been a decrease in commodity costs, and some degree of leveling off is expected as the United States completes economic recovery. It is not possible to reasonably forecast weather future commodity prices will increase, decrease, or they remain same. Although the costs in 2009 are much higher than earlier in the decade, for modeling purposes, the cost presented here do not anticipate dramatic increases or decreases in basic commodity prices through 2050.Cost trajectories were assumed to be based on technology maturity levels and expected performance improvements due to learning, normal evolutionary development, deployment incentives etc.

2. COST AND PERFORMANCE DATA FOR ENERGY STORAGE TECHNOLOGIES

Selecting a representative definition for compressed air energy storage (CAES) and pumped-storage hydropower (PSH) technologies that can then be used to identify a representative cost is extremely difficult; one problem is that a very low cost can be estimated for these technologies if the best circumstances are assumed (e.g., use of existing infrastructure). For example an assumption can be made for CAES that almost no below ground cost is contributed when building a power generation plant that can be accommodated by an abandoned gas well of adequate size .For PSH, one can assume only two existing reservoirs need to be connected with a pump and turbine at a lower reservoir by Identification technical report NREL/SR-6A2-46877 et al.[1] Work performed by Black and Veatch Corporation, Overland Park, K.S Golden, CO: National Renewable Energy Laboratory.

These scenarios are entirely different from possible low cost or mid-cost options. While this situation makes identifying a reprehensive, or average, power plant difficult, this selection must made before the discussion of costs can be opened. The design options and associated costs for CAES and PSH are unlimited. Another issue with PSH is that transmission has been equally challenging with cost and environmental issues limiting pumped options no CAES or PSH plants have been built recently. Further, in the case of PSH, the Electric Power Research Institute (EPRI) has indicated, scarcity of suitable surface topography that is environmentally acceptable is likely to inhibit further significant domestic development of utility pumped-hydro storage.

The disadvantage of the storage estimates initially selected is that they might not adequately reflect the very lowest cost options that may eventually be available. However, the advantage is that they are examples of what real developers have recently considered for development, developers have considered power plant with these costs and details. They are not the least cost examples that could someday be available for consideration by developers, but they are recent examples of site and technology combinations that developers actually have had available for consideration. In addition, the PSH example is of relatively small capacity that may be suitable in a large number of locations, it is not a less expensive, a larger capacity system that may not be as available in many parts of the country. Lastly, because Black and Veatch view the costs as mid-range, they must be considered reasonably conservative. Black and Veatch recently organized that it could have chosen lower cost by HIS Cambridge energy research associates et al.[2] Power Capital Costs Index Shows Construction Costs

2.1 COMPRESSED AIR ENERGY STORAGE (CAES) TECHNOLOGY

A confidential CAES in –house reference study for an independent power producer has been used for the point estimate, and the range was based on historical data. A two –unit recuperated expander with storage in a solution –mined salt dome was assumed for this estimate. Approximately 262 MW net with 15 hours of storage was assumed to be provided. Coulomd.L., and Neuhoff. K. et al [3] Five compressors were assumed to be included. A 2010 capital cost was estimated at 900$/Kw-30%+75%.No cost improvement was assumed over time. Table 1 presents costs and performance data for CAES. Table 2 presents emission data for the technology

Table 1 Cost and Performance Projection for Compressed Air Energy Storage (CAES) Plant (262 MW)

Year	Heat Rate (Btu/kWh)	Capit al Cost ($/kW)	Variable O&M ($/MWh)	Fixed O&M ($/kW-year)	Round-Trip Efficiency	FOR (%)	POR (%)	Construction Schedule (Months)	Min. Load (%)	Spin Ramp Rate (%/min.)	Quick Start Ramp Rate (%/min.)
2008	4910	927	–	–	–	–	–	–	–	–	–
2010	–	–	–	–	–	–	–	–	–	–	–
2015	4910	900	1.55	11.6	1.25	3	4	18	50	10	4
2020	4910	900	1.55	11.6	1.25	3	4	18	50	10	4
2025	4910	900	1.55	11.6	1.25	3	4	18	50	10	4
2030	4910	900	1.55	11.6	1.25	3	4	18	50	10	4
2035	4910	900	1.55	11.6	1.25	3	4	18	50	10	4
2040	4910	900	1.55	11.6	1.25	3	4	18	50	10	4
2045	4910	900	1.55	11.6	1.25	3	4	18	50	10	4
2050	4910	900	1.55	11.6	1.25	3	4	18	50	10	4

Table 2 Emission Rates for Compressed Air Energy Storage

SO_2 (lb/ hr)	NO_x (lb/hr)	Hg Micro (lb/hr)	PM10 (lb/hr)	CO_2 (kpph)
3.4	47	0	11.6	135

The capital cost breakdown for the CAES plant is shown in Figure 1. CAES plant cost savings will occur in all cost categories over time.

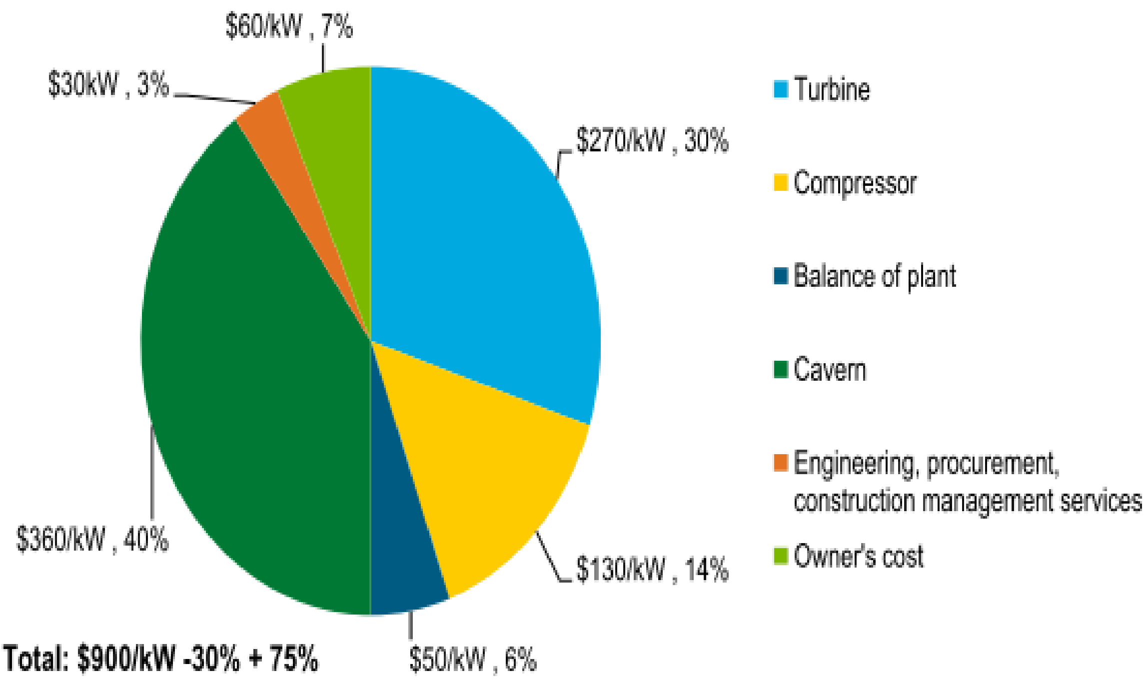

Figure 1. Capital cost breakdown for a compressed air energy storage power plant

2.2 PUMPED-STORAGE HYDROPOWER TECHNOLOGY

A confidential in house reference study for an independent power producer was used for the point estimate, and the range was established based on data. The PSH cost estimate assumed a net capacity of 500 MW with 10 hours of storage. A 2010 capital cost was estimated at 2,004$/Kw+50%. This is a mature technology with no cost improvement assumed over time. Kane. M. et al.[4] A list of current preliminary licenses indicates an average size between 500MW and 800MW. Cost and performance data for PSH are presented in Table 3.

Table 3. Cost and Performance Projection for a Pumped-Storage Hydropower Plant (500 MW)

Year	Capital Cost ($/kW)	Variable O&M ($/MWh)	Fixed O&M ($/kW-yr)	Round-Trip Efficiency (%)	FOR (%)	POR (%)	Construction Schedule (Months)	Min. Load (%)	Spin Ramp Rate (%/min.)	Quick Start Ramp Rate (%/min.)
2008	2297	–	–	–	–	–	–	–	–	–
2010	2230	0	30.8	0.8	3.00	3.80	30	33	50	50
2015	2230	0	30.8	0.8	3.00	3.80	30	33	50	50
2020	2230	0	30.8	0.8	3.00	3.80	30	33	50	50
2025	2230	0	30.8	0.8	3.00	3.80	30	33	50	50
2030	2230	0	30.8	0.8	3.00	3.80	30	33	50	50
2035	2230	0	30.8	0.8	3.00	3.80	30	33	50	50
2040	2230	0	30.8	0.8	3.00	3.80	30	33	50	50
2045	2230	0	30.8	0.8	3.00	3.80	30	33	50	50
2050	2230	0	30.8	0.8	3.00	3.80	30	33	50	50

The capital cost breakdown for the pumped-storage hydropower plant is shown in Figure 2. Pump hydroelectric power plant cost savings will occur primarily in the powerhouse category over time.

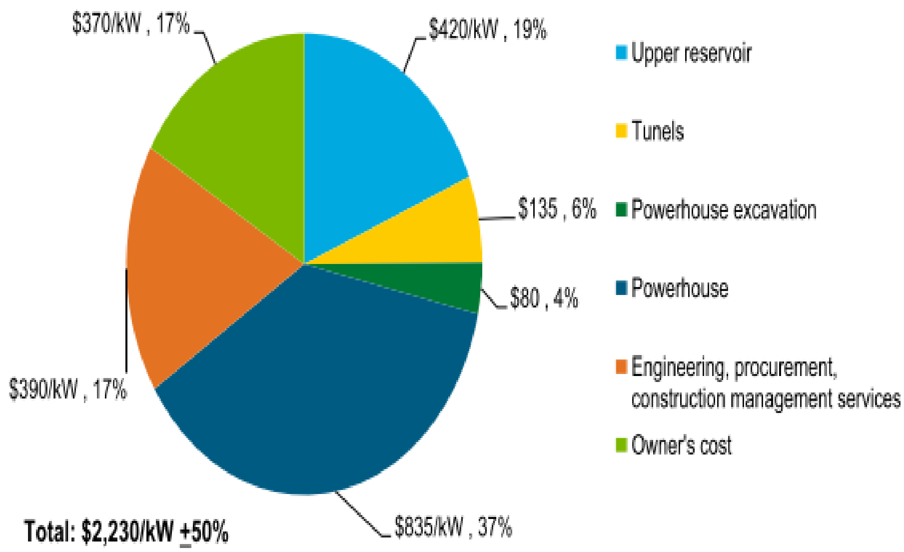

Figure 2. Capital Cost breakdown for a pumped-storage hydropower plant

2.3 BATTERY ENERGY STORAGE TECHNOLOGY

A confidential in –house reference study for an independent power product has been used for the point estimate, and the range has been established based on data. The battery proxy was assumed to be sodium sulfide type with a net capacity of 7.2 MW. The storage was assumed to be 8.1 hours. Folley. M et al.[5] A Capital cost is estimated at 3,990$/kW (or 1,000$/kW and 350 $/kWh) + 75%. Cost improvement over time was assumed for development of significant number of new battery options. Table 4 presents' cost and performance data for battery energy storage. The O and M cost includes the cost of battery replacement every 5,000 hours.

Table 4. Cost and Performance Projection for a Battery Energy Storage Plant (7.2 MW)

(Year)	Capital Cost ($/kW)	Variable O&M ($/MWh)	Fixed O&M ($/kW-yr)	Round-Trip Efficiency (%)	FOR (%)	POR (%)	Construction Schedule (Months)	Min. Load (%)	Spin Ramp Rate (%/sec)	Quick Start Ramp Rate (%/sec)
2008	4110	–	–	–	–	–	–	–	–	–
2010	3990	59	25.2	0.75	2.00	0.55	6	0	20	20
2015	3890	59	25.2	0.75	2.00	0.55	6	0	20	20
2020	3790	59	25.2	0.75	2.00	0.55	6	0	20	20
2025	3690	59	25.2	0.75	2.00	0.55	6	0	20	20
2030	3590	59	25.2	0.75	2.00	0.55	6	0	20	20
2035	3490	59	25.2	0.75	2.00	0.55	6	0	20	20
2040	3390	59	25.2	0.75	2.00	0.55	6	0	20	20
2045	3290	59	25.2	0.75	2.00	0.55	6	0	20	20
2050	3190	59	25.2	0.75	2.00	0.55	6	0	20	20

The Capital cost breakdown for the battery energy storage plant is shown in Figure 3. Battery storage energy storage plant cost reductions will occur primarily in the battery cost category over time.

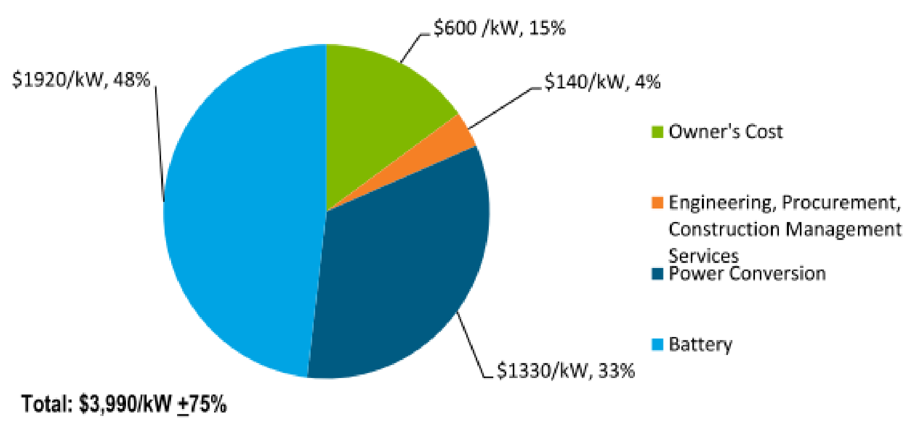

Figure 3. Capital Cost Breakdown for a Battery Energy Storage Plant

3. CONCLUSIONS AND FUTURE WORK

These low cost solutions can be compared to high cost solutions, for CAES, excavation of an entire cavern out of hard rock could be assumed, and for PHS construction of new reservoirs and supply of pump/turbine and interconnections between reservoirs could be assumed. CAES plant cost savings will occur in all categories over time. Pumped hydroelectric power plant cost savings will occur primarily in the power house categories over time. Battery energy storage plant cost reductions will occur primarily in the battery cost category over time. Cost and Performance Projection for Compressed Air Energy Storage (CAES)Plant Approximate 262 MW net with 15 hours of storage was assumed to be provided. Five compressors were assumed to be included. A 2010 capital cost was estimated at 900$/Kw-30%+75%.No cost improvement was assumed over time. The cost and performance projection for a pumped-storage hydropower plant 500 MW the PSH cost estimate assumed a net capacity of 500 MW with 10 hours of storage. A 2010 capital cost was estimated at 2,004$/Kw+50%. The cost and performance projection for battery energy storage plant 7.2 MW the battery proxy was assumed to be sodium sulfide type with a net capacity of 7.2 MW. The storage was assumed to be 8.1 hours. A Capital cost is estimated at 3,990$/kW (or 1,000$/kW and 350 $/kWh) + 75%. Cost improvement over time was assumed for development of significant number of new battery options.

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