PRICING ENERGY STORAGE FOR A BALANCED MARKET PENETRATION

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Abstract

With all the efforts put into reducing the storage cost and increasing its value in bundled applications, it is only a matter of time before the phrase “storage is too expensive” will be replaced with the question “what is the right price for energy storage?” The purpose of this paper is to apply approaches for estimating market penetration with the sales of energy storage for grid applications in order to find a price that would balance profit against market penetration to benefit both vendors and end users of energy storage. It may appear to be premature to talk about an optimum sales price that is lower than the current market price at a time when most storage vendors are struggling to survive. However, looking over the horizon would benefit all stake holders in the energy storage community and help prepare a better roadmap into this evolving market.

Keywords: Energy Storage Pricing, Market Penetration, S-Curve, Payback, Optimum Price, Maximum Sales Potential, Cost, Value, Grid Applications

MARKET PENETRATION FOR ENERGY STORAGE

Market Penetration forecasting can be used to estimate market growth when there is little history or data on the market performance of a new product [1]. While the use of energy storage for grid applications is an established concept, storage technologies and application concepts have evolved significantly over the last decade. Therefore, there is little historical information available today about the market successes of new storage options.

NREL’s report on the market penetration of new energy technologies offers a very comprehensive overview of different market penetration models focused on energy technologies [2]. Figure 1, borrowed from this report, identifies different market penetration potentials from projection to theoretical potentials. Market projection (the smallest section) is the focus of the market penetration analysis used in this paper.

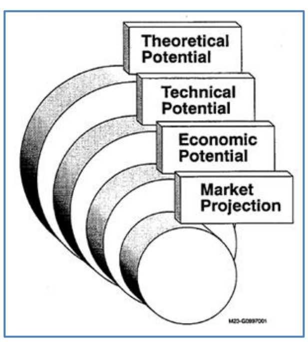

Fig 1 – Different market penetration potentials for new technologies (picture from NREL report [2])

The NREL report explains different forecasting methods and diffusion models for market penetration ranging from the Bass model (1969) that is the most general approach to Kalish and Lilien model (1986) that treats adoption or market penetration as a function of price.

The market penetration model presented in this paper can be shown as a non-linear S-Curve that is also referred to as the sigmoid cumulative adoption function. It shows market penetration as a function of the technology payback. As shown in Figure 2, the longer the payback of a storage project, the smaller the market penetration or amount (MWh) of storage sold. Some models use S-curves which are symmetric about its inflection point, and others use non-symmetric S-Curves. Here, we illustrate our approach using a symmetric S-Curve.

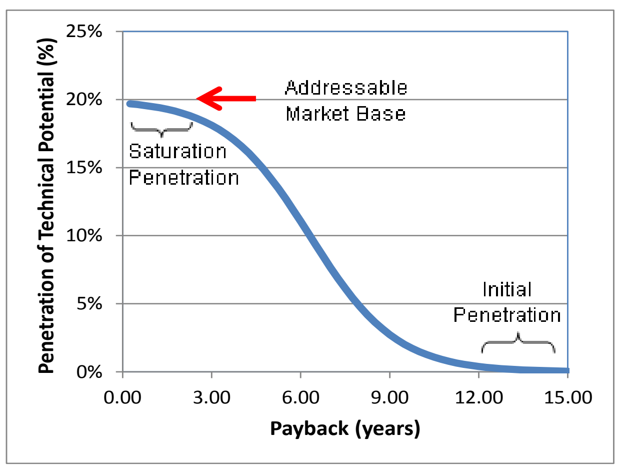

Fig 2 –Example of an S-Curve for a developing market

Depending on the type of product and the readiness of the market for it, the addressable part of a market (maximum penetration with payback less than one year) is often 10%-40% of its potential.

For any given application and its realizeable value, payback itself is a nonlinear function of the storage price and would not exist above certain price point (no payback). Figure 3 shows an example of a storage payback as a function of its price ($/kW) for a given grid application with an estimated value of $ 360 / kW per year. Approximately 38% has been added to the storage price to cover installation and present value of annual operation and maintenance expenses. This chart would vary with application types and their storage requirements.

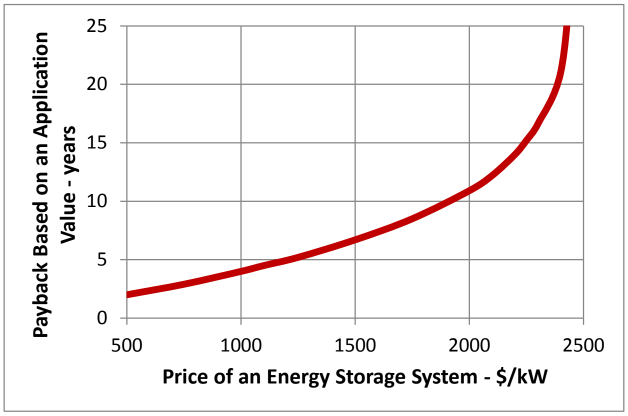

Fig 3 –Payback vs. the price of an energy storage

Now if the above two nonlinear relationships (curves) are combined, we find the market penetration as a function of the price of a storage system for the grid application considered in this example. Figure 4 shows this relationship with the market penetration converted from percentage into actual MW assuming that the targeted grid application has a 10-year market potential of 2,500 MW.

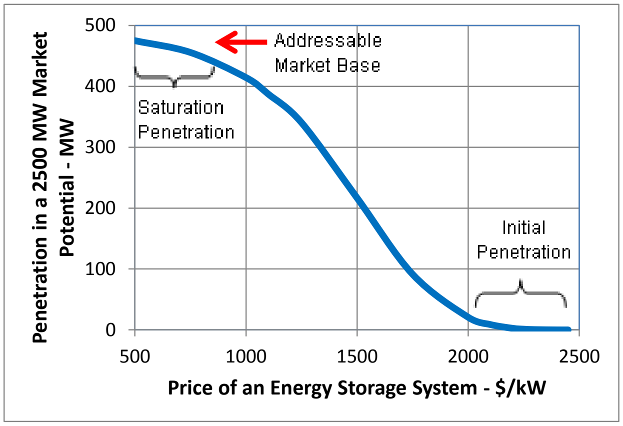

Fig 4 –Example of market penetration vs. price

Pricing for the Maximum Sales and Profit Potentials

The total sales potential (product of the storage price by the market potential) may be expressed as a function of the storage price. As shown in Figure 5, the total sales potential goes through a maximum at a certain storage price point. Selling storage above or below this price point would reduce the total sales potential.

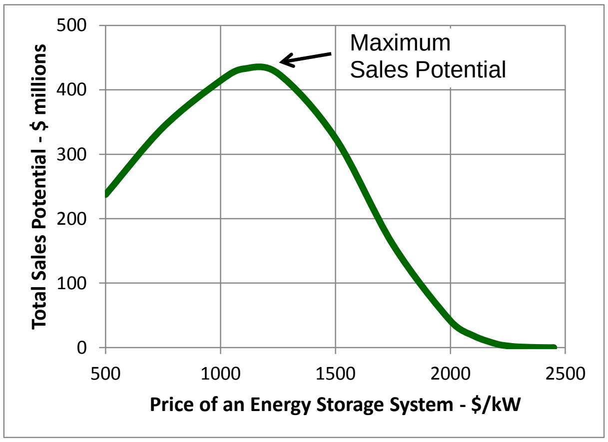

Fig 5 –Example of pricing for the maximum sales potential

It should be noted that the storage price which brings the highest sales potential does not maximize vendors' profit potential. To obtain the price for maximum profit, a vendor has to subtract the cost of making his product. This manufacturing cost varies widely for different energy storage technologies. Figure 6 shows the adjustment for a manufacturing cost of $1,000 / kW.

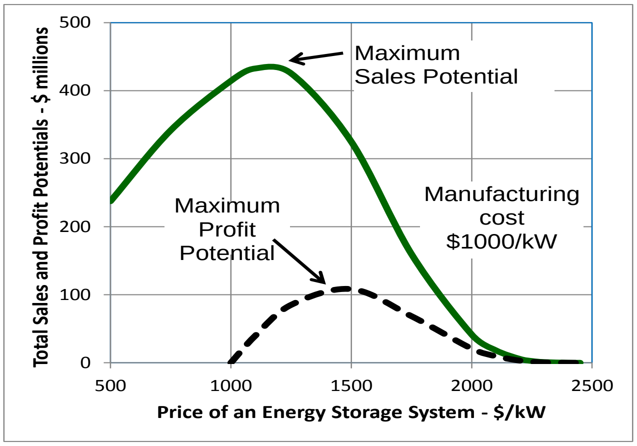

Fig 6 Storage price for maximum sales and profit potentials

IMPLEMENTATION OF ENERGY STORAGE PRICING

Optimum storage pricing for maximum sales and profit potential is influenced by many parameters including:

- Market readiness or penetration models that may be simplified in the following three scenarios
  - sluggish market (about 10% of its potential is addressable)
  - evolving market (about 20% of its potential is addressable)
  - already started market (about 40% of its potential is addressable)
- Reasonable or expected payback for any particular application (impacts the shape of the S-Curve)
- Market price sensitivity that defines the slope of S-Curve
- Storage deployment cost including installation, maintenance and operational costs
- Actual cost of operating a storage system or offering a storage service.

In order to study the optimum storage pricing for different grid applications, energy storage devices, market penetration scenarios and other factors that impact it., DNV KEMA used its ES-Select tool as a platform since it already has extensive databases on the benefits and markets of grid applications as well as cost components for a wide range of energy storage technologies. Another reason for trying this on ES-Select is that a public version of that tool is currently available from DOE through SANDIA website (www.sandia.gov/ess) and it could, at some point, also be put on the public version of the tool for public use.

The mathematical model for the S-Curve representing the market penetration has been expressed in many forms and equations to fit different products and markets [2]. This paper offers a simplification of these equations that appears to make more sense to the users and other stakeholders of energy storage technologies and applications. Below is the simplified equation:

$$Penetration = \frac{Pmax}{1-e^{S\left(\frac{x}{H}-1\right)}} \qquad (1)$$

Where:

Penetration is in per units (less than 1 or 100%)

X is the payback time in years (variable of the equation)

Pmax is the maximum penetration when payback is less than a year. This is also referred to as addressable market base. In most cases, Pmax ranges from 0.1 (sluggish market) to 0.4 (already established market)

H is the market's half-value payback time beyond which more than half the addressable market will be lost (this is expected to in the 7-14 year range). This at the S-Curve's point of infliction.

S is the sensitivity to payback or slope of the S-Curve and is dimensionless with a numerical value between 5 (not sensitive) to 10 (price sensitive). At S=10, the difference between the paybacks for no market penetration and full market penetration is about 5 years. At S=5 this difference expands to about 10 years

Figure 7 shows the impacts of these parameters on the S-Curve shape.

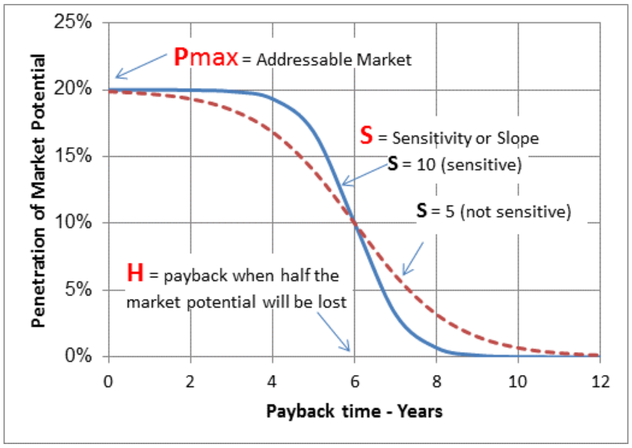

Fig 7 – Simplified parameters of a market penetration S-Curve

Figure 8 shows implementation of the market penetration S-Curve and study of the optimum pricing for a bundled application of distribution and transmission deferrals. The key parameters selected for this chart, as shown on the screenshot are:

- Market Readiness (Addressable base) = "Evolving" = 20%
- Market Sensitivity to storage price = "Low", S=5
- Reasonable Payback = 7 years
- Application average annual value = \$556.7/kW per year
- Market potential over the next 10 years = 5670 MW
- Cost or producing a storage solution = \$1000/kW

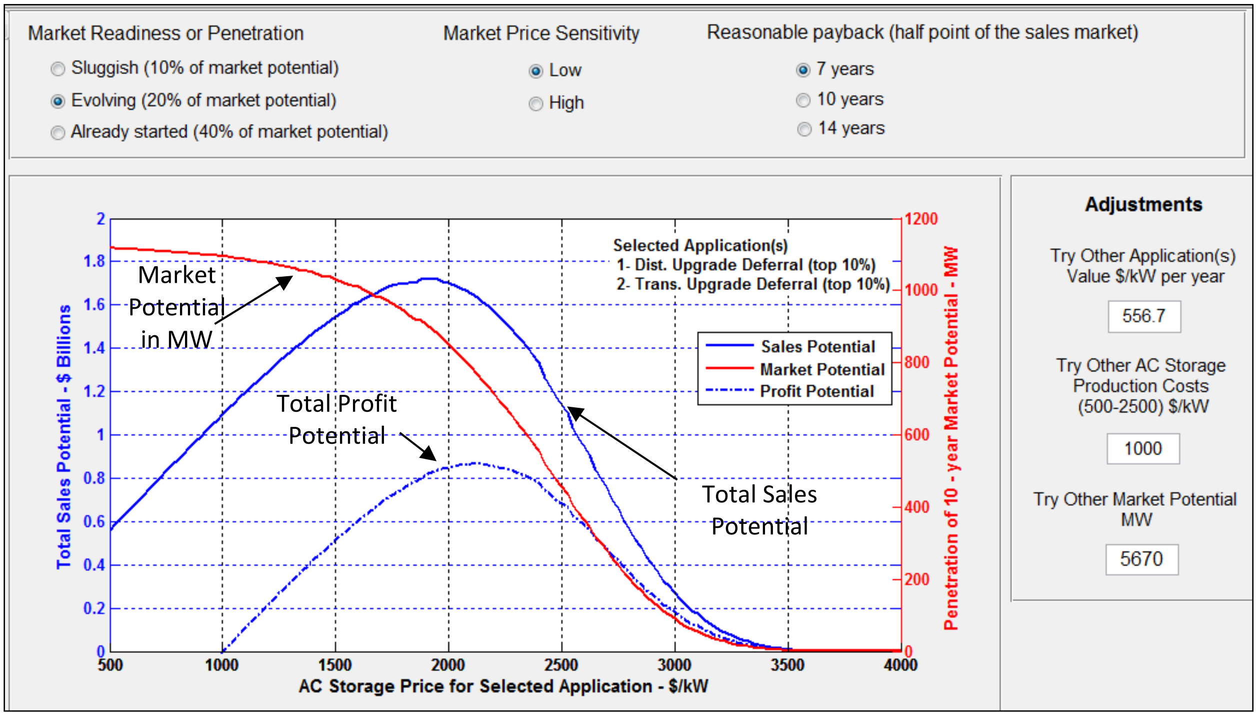

Fig 8 – Screenshot of ES-Select showing implementation of the market penetration model to obtain the optimum storage pricing.

It should be noted that storage price is the purchase price of storage and, in order to calculate the payback correctly, installation and operational cost as well as its maintenance cost need to be considered. ES-Select uses the average of these extra costs for different storage technologies and adds that to the storage price before calculating the payback and market penetration.

SENSITIVITY ANALYSES

Two sets of sensitivity analyses were done; sensitivity of the optimum price to its controlling factors and sensitivity of the maximum profit potential to its controlling factors.

1- SENSITIVITY OF THE OPTIMUM PRICE

Impact of Application(s) Value

Figure 9 shows the impact of the application(s) value on the optimum price for maximum profit potential. The approximate location of different applications is shown on this chart.

It is noted that, for every $100/kW (per year) increase in the annual value of a storage application, the optimum sales price would increase about $300/kW.

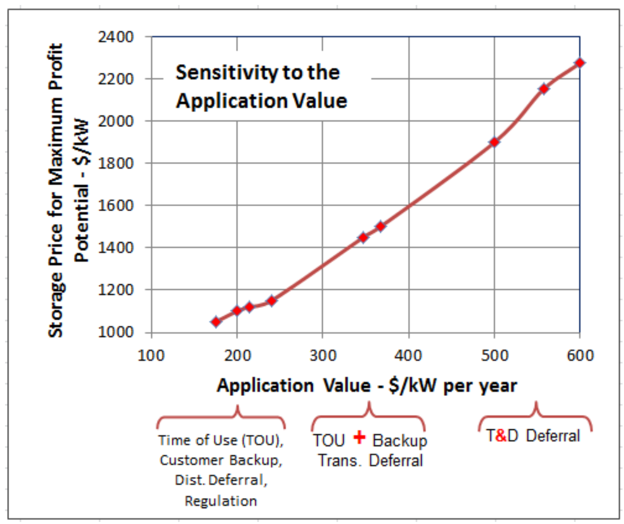

Fig 9 – Sensitivity of the optimum storage price to the applications' value.

Impact of the Market's Half-value Payback Time

To gauge this sensitivity, the half-value payback time has been changed between 7 and 14 years. Figure 10 shows the sensitivity of the optimum storage pricing to this payback time.

It is noted that, for the case considered in this example, increasing the S-Curve's center point (half-value payback time) by one year would allow selling that storage device at $100/kW more.

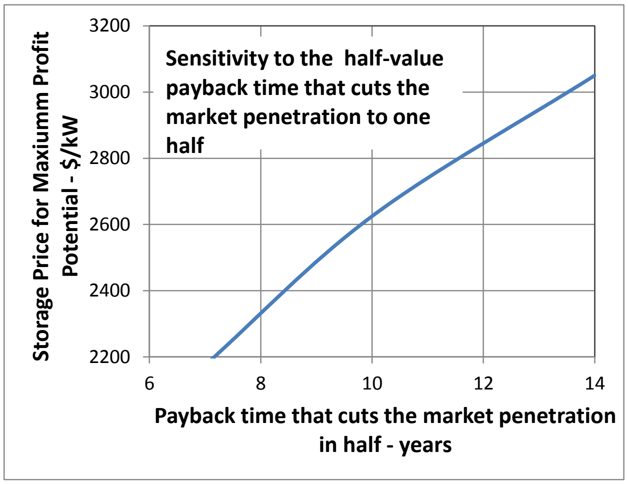

Fig 10 – Sensitivity of the optimum storage price to the half-value payback time.

Impact of the storage manufacturing cost

While the price for maximum sales potential is mainly a function of the application value and almost independent of the storage type, the price for maximum profitability does depend on the storage as it is strongly affected by the manufacturing cost of the storage. Figure 11 shows the sensitivity of the optimum storage price for maximum profitability to the storage manufacturing cost.

It is noted that, for the case used in this example, a $100/kW reduction in the manufacturing cost would only allow reducing the sales price by about $25/ kW while staying at the optimum pricing point.

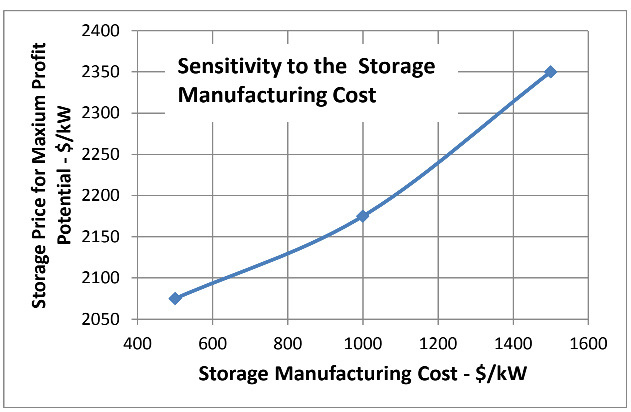

Fig 11 – Sensitivity of the optimum storage price to the manufacturing cost of energy storage

Sensitivity of the optimum price to other factors

In the case used for the example shown in this paper, following factors had negligible impact on the optimum price for maximum profitability potential:

- Market Sensitivity - S factor in equation (1)
- Market Potential
- Addressable Market

Market potential and its addressable amount would directly impact the total sales and profit potential but have no impact on the optimum pricing.

2- SENSITIVITY OF THE MAXIMUM PROFIT POTENTIAL

Two of the most significant factors on the maximum profit potential are the application value and the storage cost. These two factors, however, impact the maximum profit potential very differently. Figure 12 compares the sensitivity of the profit potential to variations in these two parameters.

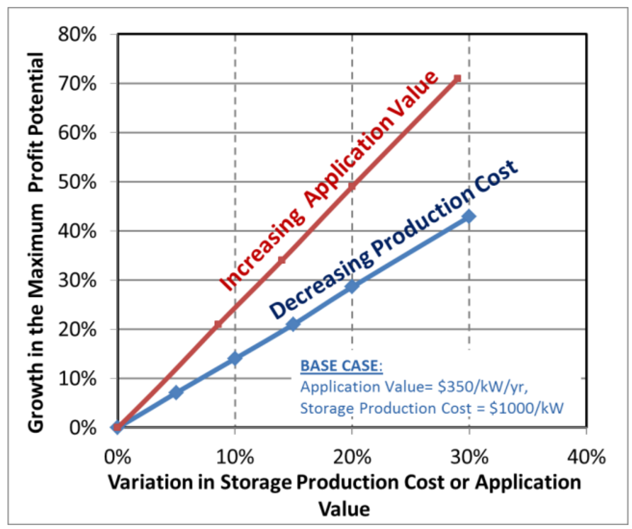

Fig 12 – Sensitivity of the maximum profit potential to cost reduction vs. increasing application value.

A clear conclusion from this sensitivity analysis is that storage vendors may find it more profitable, in the long term, to offer sophisticated controls and other features that would enhance the total value that their storage device could help realize (such as serving multiple applications) rather than just cutting their production cost. This trend was confirmed on a variety of different application values and storage cost ranges, in addition to the base case used for Figure 12.

REMARKS

Pricing a product for an evolving market that has little precedence or historical data is a complicated challenge. This is particularly true for energy storage devices that offer multiple services and the values of those services is still evolving and under investigation. The optimum pricing guidelines discussed in this paper are only a starting point and need to be revisited and further developed. Following are just a few of the gaps in this study that need to be addressed in the next iteration on the concept of optimum pricing:

- Competitive pricing
- Innovators starting a fresh market vs. imitators benefiting from established markets
- Development of storage technologies with time and its impact on market adoption

Diffusion models typically consider the technology not to improve over time or react to the market reactions. This certainly is not valid for energy storage

CONCLUSIONS

Application of the market penetration S-Curve to energy storage allows us to investigate the optimum pricing for maximum total sales or profit from sales of the energy storage systems.

The value of knowing where the optimum storage price or maximum profit potentials are for any grid application is very clear to vendors. Buyers and other stakeholders would also benefit from this information. The sale of a storage product at or near its optimum price would maximize the sales and installation of storage on the grid. Besides the benefits to the grid, the increased sales would also accelerate further price reduction and standardization of the storage solutions that would benefit everyone. The following observations were made or confirmed in this study:

1. Optimum storage price for maximum sales potential is unique for each application or bundle of multiple applications. This is almost independent of the storage technology except that different storage technologies have different installation and operation costs that need to be considered in calculating paybacks.
2. Optimum storage price for maximum profit potential is a function of the energy storage technology because each storage technology has a different manufacturing cost.
3. While the sales and profit potentials are directly dependent on the market potential of each application and its addressable amount (the sales when payback is less than 1 year), optimum storage price for maximum profit potential is very sensitive to the value of each application.
4. The maximum profit potential is more sensitive to variations in the application value than storage price. Therefore, storage vendors may find it more profitable to focus on increasing the total value their product rather than just cutting the production cost.

References

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[2] Daniel J. Packey , “Market Penetration of New Energy Technologies”, NREL/TP-462-4860, Feb 1993