# Growth in Energy Storage Applications Creates Demand for Greater Copper Usage

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## ABSTRACT

The Copper Development Association Inc. (CDA) commissioned a KEMA study on grid energy storage in the U.S. and the emerging demand for copper in this market. Current initiatives shaping the energy storage market were studied, in order to forecast future markets for energy storage and copper demand. The scope of the study included electrochemical, mechanical and thermal storage technologies as well as grid applications ranging from distributed community energy storage (CES) to centralized, bulk storage. Focus was on four applications: ancillary services, transmission services, community energy storage and other distributed storage. To forecast demand for copper, the copper contents of storage-devices were estimated from knowledge of storage materials and information provided by storage developers.

*Keywords*: grid, energy, storage, copper, forecast

## 1 INTRODUCTON

Energy storage technology holds the promise to provide many benefits across the energy delivery value chain, which includes all the intermediary steps from generation, to transmission and distribution, to end-users.

Energy storage technology is widely viewed as a key component for integration of high levels of renewable energy penetration and as an essential tool for smart, future electricity grids. It provides societal benefits such as reducing emissions, serving as an alternative to a traditional generation plant, or acting as a tool for demand response.

Energy storage has been a part of our electric energy system for decades. Pumped-hydro, for example, is a well-known technology with mature applications installed globally. The concept of compressed air energy storage (CAES) has also been known for many years, as has the use of lead-acid batteries in power systems applications.

Newer energy storage technologies are in the early market adoption stages. Examples are lithium-ion batteries, flow batteries, flywheels, and sodium-sulfur battery (NaS) systems. They offer improved operational flexibility, improved charge/discharge cycle life, and in some cases longer duration or fast response capabilities.

The next two sections outlines information about energy storage technologies and the types of grid services they can enable, or the applications they can provide. That is followed by a recap of the highlights of the KEMA study, including forecasts from 2012 of demand for energy storage as well as the projected demand for copper. For more about the methodology, specifics on energy storage initiates and detailed analyses of the copper content projections, the reader is referred to the original KEMA study, which is currently available online from the Copper Development Association [1].

## 2 ENERGY STORAGE TECHNOLOGIES

The term "energy storage" refers to a number of different types of storage technologies, including those whose primary methods are electrochemical, mechanical or thermal. Within these technology types, a variety of storage products exist today or are under development. The different types of products and technologies carry with them performance characteristics and costs that make them more or less suitable for given applications. For example, some applications may emphasize fast response over duration, while others require longer durations. As such, no technology fits all applications.

Storage technologies are offen classifed according to two characteristics commonly used for different technologies: rated power and discharge duration. Together, they describe how much power a storage unit can provide (in MW) and for how long (in hours). Overall, there is a great deal of overlap in technology ratings, and even within a given technology type, the range of ratings can be large. The specific products ultimately determine the storage characteristics by unit and are often tailored to the applications for which they are designed.

Apart from performance characteristics, capital and operating costs also determine whether a technology is viable for a given application. For example, though a product might be suited technically for a given application, the cost of the product might not justify its costs. Ultimately, the answer to which storage device is best for a given application depends on its technical capabilities as well as the financial viability of the product, based on product costs and application revenues.

Two additional factors that can affect the lifetime costs of an energy storage device, which are also used commonly to describe storage features, are efficiency and cycle life. Cycle life refers to the number of charge and discharge cycles that a storage device can provide before performance decreases so as to make it no longer capable of suitably performing the functions it needs to in an application.

# 3 GRID APPLICATIONS

Energy storage has the ability to serve multiple grid services. A report by Sandia National Laboratories, for example, identifies 19 different energy storage grid services [2]. These grid services have specific requirements, such as duration and response times. Using current energy storage costs under current energy market policies and regulations, it can be difficult to justify the cost of an energy storage device for a single application. As such, it is possible that products would combine several applications, which have both technical and business compatibility, to help make energy storage investments economically more feasible.

The potential markets for many of these applications are large. In the KEMA study, application market potential is based on a sampling of industry analyses, including those from Sandia National Laboratories and the Electric Power Research Institute

As the name implies, grid storage is connected at various locations along the electric grid system, ranging from distributed energy storage at the community scale on the order of kilowatts (kW) in capacity, to large-scale battery energy storage on the order of 1–2 MWs often aggregated up to 50 MW in size, and to bulk grid storage on the order of tens of MWs.

The applications analyzed by KEMA include those which KEMA believes have the largest near-term market growth. These include CES, ancillary services, transmission services, renewables energy integration and other distributed storage. The following provides a brief description of each.

## 3.1 CES Application

CES is a small, distributed energy storage unit connected to secondary transformers serving a few houses or small commercial loads. As the name implies, local communities are the primary beneficiaries of an energy storage device—CES enhances reliability, reduces the required capital investment by flattening peak loads, compensates for the variability of distributed renewable resources, such as roof top solar photovoltaics (PV), and provides a source of back-up power during grid events for residential and commercial and industrial customers. As such, it combines multiple applications to serve grid needs at the end of the distribution system.

## 3.2 Ancillary Services

Ancillary services are tools used by grid operators to help maintain a continued balance between electricity production and demand. Fast-response storage devices have the ability to provide frequency regulation and spinning reserve grid services, a subset of the full set of ancillary services.

Independent system operators and regional transmission organizations (ISOs/RTOs) are currently examining the potential for fast-response storage devices to act as an alternative to traditional generation technologies to help balance system supply and demand through regulation and spinning reserves services.

In addition, increased implementation of variable renewable generation resources, especially wind and solar, may increase grid volatility, requiring an increased need for frequency regulation services. Advanced energy storage technologies with fast-response capabilities show promise as a potential solution to addressing the volatility introduced by renewables.

## 3.3 Renewable Energy Integration

The renewable energy integration application is directly linked to intermittent renewable implementation on the grid (e.g., wind and solar) and the amount that occurs on a percentage basis. Energy storage can address three "buffering" challenges that variable energy resources introduce on the grid system: 1) *Capacity firming*, as previously discussed under ancillary service/regulation; 2) *Smoothing or ramp control*, a function to help reduce the adverse impacts of a very fast change in renewable generation level or output; and 3) *Time-shifting*, to match typically off-peak renewable energy supply with on-peak demand.

Some of the services provided in the ancillary services market will help with the integration of renewable resources. However, it remains to be seen whether the intermittency of renewable resources will be addressed in the markets or outside of them. For example, today, obligations to firm wind capacity—that is to maintain the power output at a committed level for a reasonable time—vary by region. For the most part, the obligation lies with the ISO/RTO. However, there has been movement toward requiring generators of intermittent or variable energy resources to firm their power to minimum requirements before placing their power on the grid. Separately, needs such as management of localized voltage issues could potentially still be addressed by energy storage outside of market-based services.

## 3.4 Transmission Services

Transmission services include primarily the deferral of transmission and distribution equipment, or "T&D deferral," transmission congestion and transmission support. T&D deferral is the use of storage to defer the installation or upgrade of transmission and distribution equipment, which can often be difficult to site. Transmission support refers to the use of storage to address electrical anomalies and disturbances on the grid. Transmission congestion relief refers to the use of storage to avoid the need to transmit power during periods of high system demand. For example, energy stored by devices could be used during on-peak hours when the transmission systems are congested.

## 3.5 Other Distributed Storage

Additional distributed grid storage applications besides CES are under development. For example, thermal storage currently constitutes a large portion of the storage market today. Here, storage can be used to help shift cooling or heating loads to off-peak hours. More recently, thermal storage associated with water heaters has demonstrated the ability to participate in the ancillary services markets. In addition, microgrid demonstrations are underway that integrate storage into the portfolio of onsite resources, such as distributed generation or demand response capability. Furthermore, storage can play a role in assisting with integrating intermittent renewables on a customer site, and with providing temporary back-up power services.

# 4 COPPER DEMAND RESULTS

Based on the U.S. energy storage market assessment and analysis of the copper intensities of storage device and their installations, the KEMA research finds that the U.S. market for grid energy storage could result in a sizeable demand for copper. In particular, the copper intensity of storage installations appears to be significant though varied, ranging from zero to over four tons per megawatt (MW), depending on the installation configuration, type of electrical equipment and storage type.

The total incremental copper demand associated with U.S. grid energy storage is estimated to range from roughly 900 tons of copper to over 3,000 tons of copper. Additional findings from this research are noted below, by topic area.

## 4.1 Demand by Market Segment

Applications for renewable energy integration and ancillary services appear to have the largest near-term associated demand for copper, with additional copper intensive applications, such as CES, poised for strong growth.

Renewable energy integration applications for energy storage appear to have a strong associated demand for copper. Because of the timelines of pumped hydropower investment, lithium-ion, compressed air energy storage (CAES) and lead acid storage are the largest contributors for this market. Estimates for the cumulative associated copper demand range from more than 650 tons to almost 2,200 tons, depending on the existence of financial incentives. The associated incremental copper demand ranges from over 300 tons to over 1,800 tons.

Energy storage for ancillary services also appears to have a strong associated demand for copper, due to its relatively high copper intensities and relatively high expectations for near-term growth. Estimates for the cumulative associated copper demand range from more than 630 tons to almost 840 tons, depending on the existence of financial incentives. The associated incremental copper demand ranges from over 520 tons to over 720 tons.

Though the market for distributed thermal storage is relatively large, the copper intensity is relatively limited, limiting the overall associated copper demand of this segment. Other types of distributed energy storage have higher copper intensities, but will likely have limited market penetration over the next five years. Estimates for the cumulative associated copper demand range from more than 100 tons to 160 tons, depending on the existence of financial incentives. The associated incremental copper demand ranges from over 50 tons to over 100 tons.

The market for transmission-related storage applications is potentially limited in the near term, though the copper intensities for these applications can be relatively strong. Estimates for the cumulative associated copper demand range from more than 85 tons to more than 250 tons, depending on the existence of financial incentives. The associated incremental copper demand ranges from over 5 tons to over 170 tons.

CES also appears to have a limited associated demand for copper in the near term, due to expectations of limited market growth over the next five years. However, because of its strong copper intensity and potential for large mid- to long-term growth, this area could have strong associated copper demand over time. Estimates of the cumulative associated copper demand range from 30 tons to almost 370 tons, depending on the existence of financial incentives. The associated incremental copper demand ranges from over 20 tons to over 360 tons.

## 4.2 Demand by Application

The demand for copper associated with the U.S. energy storage markets noted earlier comes from not only the copper content of the storage units themselves but also from the electrical equipment needed to operate the energy storage with the grid.

The copper content of grid energy storage installations appears to be significant, ranging from zero to over four tons per MW. On a per MW basis, CES installations are estimated to have the largest associated copper intensity, with a mid-range estimate of over four tons per MW. Other distributed storage could offer high copper intensity, but the majority of these installations, such as thermal energy storage, offer the lowest copper intensity at 0.04 tons per MW. Applications for renewable energy integration, ancillary services, and transmission services can range from 0.3 to 3 tons per MW.

Copper intensities can vary significantly by installation and storage technology. With many storage applications in the demonstration phase, energy storage installations have yet to conform to standard configurations. Distributed applications, however, generally have higher copper intensities because they use more lower-voltage equipment, which typically has higher copper intensity. Lower voltage components are more likely to use copper due its higher conductivity and lower maintenance requirements.

## 4.3 Demand by Energy Storage Type

At the unit level, energy storage devices range from zero to nearly 0.3 tons of copper per MW.

Copper can play a role in the fundamental design of storage units by contributing toward internal connections and current collectors in battery technologies or motors for pumped storage or CAES devices.

Lithium-ion, flow and sodium batteries, as well as flywheels, CAES and pumped hydropower, are strong users of copper at the unit level, ranging from over 0.10 to nearly 0.3 tons per MW.

Thermal storage, lead-acid batteries, and super capacitors exhibit the lowest copper intensities, ranging from 0 to 0.03 tons per MW.

## 4.4 The U.S. Energy Storage Market

Overall, opportunity abounds as the market is strong and robust and has large potential. However, the market is still developing with technology and policy still evolving. The market needs to continue with initiatives to reduce costs and increase experience in order for growth to meet expectations. KEMA estimated that the U.S. grid storage market could grow to between two to four gigawatts (GW) by 2017, depending on the existence of financial incentives.

Many new technologies are under development and a handful are ready for commercialization.

Mature energy storage technologies currently constitute the majority of the energy storage market today. These include thermal energy storage, pumped hydropower and CAES. In the near term, battery technologies and thermal storage are expected to have the strongest growth areas.

Second generation technologies are emerging and research is continuing to be fruitful. Venture capital investment is booming both inside and outside of the U.S.

The ability to scale quickly is seen as a challenge, as is the ability to bring down costs. Financial incentives could have a large impact on market size by defraying initial investment costs and helping to grow the market.

The U.S. markets around grid-storage applications are still evolving. Policy developments are continuing to shape the development of markets around grid applications, and demonstrations are continuing to define grid application success and inform technology value propositions.

Markets around some of the grid storage applications are expanding now, such as ancillary services, and markets for other applications that are developing now, such as peaker plant applications, will likely come to fruition after five years.

In the near future, costs are expected to come down (via improved system integration, increased production and enhanced distribution capability), investments are expected to continue, and areas currently in the demonstration phase will likely start to commercialize.

## 4.5 Copper and Related Industries

Because of its potential role in supporting the integration of renewable energy, energy storage may also help bolster the copper demand associated with renewable generation.

Energy storage is one of many tools available to help address renewable intermittency. Energy storage can also assist in the integration of renewable energy by helping to address transmission constraints. The estimated copper intensities of typical wind farms and typical centralized solar plants, according to prior CDA studies, are three to six tons per MW and two to five tons per MW, respectively.

# 5 CONCLUSION

Commissioned by the Copper Development Association Inc. (CDA), the 2012 KEMA research report entitled "Market Evaluation for Energy Storage in the United States" evaluates the near-term market for grid energy storage in the United States (U.S.) and the copper content associated with this market. The CDA is the market development, engineering, and information services arm of the copper industry, chartered to enhance and expand markets for copper and its alloys in North America. It is a member of the Copper Alliance.

While it is difficult to accurately forecast the growth in the energy storage market, let alone the copper useage in that market, the KEMA study from 2012 shows that a robust growth in the energy storage market could result in additional demand for copper amounting to several thousand tons in the near future and perhaps much more in the long term, especially if energy storage leads to wider use of alternative energies such as wind and solar.

*Acknowledgement: Portions of this paper were adapted with permission from CDA sponsored KEMA research paper referenced below and available online from the www.copper.org website.*

# REFERENCES

[1] KEMA, "Market Evaluation for Energy Storage in the United States," January 2012, Fairfax, Virginia, 69 pages, with 27 Figures.

[2] U.S. Department of Energy, Sandia National Laboratories. Energy Storage for the Electricity Grid: Benefits and market Potential Assessment Guide. February 2010. SAND2010-0815.