A COOL ENERGY-STORAGE TECHNOLOGY PRESERVES MILK IN RURAL AREAS

Electricity shortages stunt the economic growth of many emerging economies. In India, more than $10 billion worth of fresh produce is wasted each year due to poor grid infrastructure. Without a reliable source of power, food processors in agricultural areas cannot operate refrigeration equipment economically. Their only option is to use backup diesel generators to fill the power gap. This not only doubles the capital cost of refrigeration equipment, it also triples the operating costs. In addition, diesel generators are a major source of noise and environmental pollution.

But help is on the way. Promethean Power Systems, a Somerville, MA-based small business with grants from the National Science Foundation, has developed a thermal battery-based refrigeration system to address the challenges of unreliable electricity supply in rural areas. Its patent-pending thermal battery pack can store and release large amounts of thermal energy to cool agricultural products and preserve their freshness during transport from farms to markets.

The initial application for this technology is a milk chiller that cools raw milk to 4°C in seconds to arrest bacterial growth and preserve its freshness after milking. To date, Promethean has installed more than 80 milk-chiller systems in areas throughout rural India, with a total thermal energy storage capacity of over 2 MWh. The company is also conducting field trials for a similar refrigeration system for the U.S. microbrewery market, and for chilling fruits and vegetables on farms.

▲ Fresh milk is being transported to a village collection center in hot conditions ripe for rapid milk spoilage. Image courtesy of Lance Casey and Promethean Power Systems.

The Promethean thermal battery consists of a phase-change material (PCM) submerged in a heat-transfer fluid (HTF) that is encapsulated in densely packed plastic tubes. Ethylene and propylene glycols, mixed with water, are used as the HTF because of their wide availability and low cost. The PCM consists of water containing 12–14% of a nucleating agent, such as monopotassium phosphate, to achieve target temperatures necessary for food preservation (0–5°C).

This proprietary combination of HTF and encapsulated PCM is a novel modular design approach to thermal storage that enables compact, low-cost energy storage systems with predictable performance and high heat-transfer rates.

During charging, the PCM freezes as it absorbs energy from the HTF. The PCM expands during freezing, and the tubes allow for this expansion to occur without bursting. During discharge, the PCM releases energy as it melts. The HTF remains in liquid form during charging and discharging.

To charge the battery, a refrigeration compressor cools the HTF and freezes the PCM. The compressor needs about 5 hr of grid electricity to fully charge a battery with a standard storage capacity of about 28 kWh. An automated control system consisting of a combination of software and reconfigurable hardware from U.S. suppliers starts the charging process if and when electricity is available and stops it when the battery is charged. Once the battery is fully charged, it can chill up to 700 L of milk without any additional power.

▲ Farmers pour milk on the Rapid Milk Chiller at a collection center in Tamil Nadu, India. Image courtesy of Lance Casey and Promethean Power Systems.

In India's hot climate, farmers can sometimes lose as much as 30% of their milk due to spoilage. For the world's largest producer of milk, the amount of milk lost annually in India could equal the total milk production of China. While the technology addresses a significant commercial opportunity, more importantly the rapid milk chillers have the potential to change the lives of millions of people.

"It's a win for the dairy processors because they can collect more quality milk, it's a win for the farmers because they make more money for their milk, and it's a win for the consumers because it's healthier milk," says director Sam White, who co-founded Promethean Power Systems in 2007 in Boston with Sorin Grama, the company's chief technology officer.

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