Energy Storage Can Help New York State Achieve Its Energy Goals

Liquid Metal Battery Corporation's Response to the New York State Highway Task Force's Request for Information

Proposal To	*Proposal From*	*Date*
New York Energy Highway Task Force	**Liquid Metal Battery Corporation**	**May 30, 2012**
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Executive Summary

Liquid Metal Battery Corporation (LMBC) is pleased to submit this response to the New York Energy Highway Task Force's Request for Information (RFI), issued on April 11, 2012. In its RFI, the New York Energy Highway Task Force seeks details on specific transmission, distribution and generation projects and policies that will both alleviate the burden of aging energy infrastructure in New York and allow for greater penetration of renewable energy resources. LMBC applauds the mission of the New York Energy Highway Task Force and urges the State to consider **electricity storage technologies** when evaluating the options available to meet its goals.

LMBC is an early-stage company developing a storage solution that is distinct from others in the market place today: it will be cost-effective, safe, and able to provide multiple power and energy applications (e.g., quick response ancillary services *and* long duration energy charging and discharging). The LMBC team is in the process of commercializing the Liquid Metal Battery technology and it will be more appropriate to provide full information about our solution at a later date. We decided to submit a short response to this RFI to show support for the State's initiative and provide a brief overview of our solution for reference.

When developed, the Liquid Metal Battery can help New York integrate renewable generation resources (wind and solar), avoid or defer investment in generation, distribution and transmission systems, and ease the burden of electricity congestion in demand centers. We believe that, once commercially-available, the **Liquid Metal Battery can play a significant role in helping New York achieve the objectives outlined in this RFI.**

- *Energy storage can reduce constraints on the flow of electricity to, and within, the downstate area; and expand the diversity of power generation sources supplying downstate.*

  Electricity storage located downstate can reduce transmission and distribution constraints and congestion in areas like New York City. Storage enables electricity to be generated upstate, transmitted at off peak times, stored, and then used downstate at peak times. Storage can also help address peak demand by charging during periods of low demand and discharging during periods of high demand. In this way, storage helps reduce the need for expensive and inefficient peaking plants, and new transmission and distribution lines.

- *Energy storage can help assure that long-term reliability of the electric system is maintained in the face of major system uncertainties.*

  Storage can help avoid the need for costly upgrades to aging infrastructure. Storage can also help maintain system stability as more renewable generation is added to the electric grid. In addition, storage can provide backup power for critical locations in the case of system emergencies.

- *Energy storage can encourage development of both distributed small- scale as well as utility-scale renewable generation resources throughout the State.*

  Despite all of the potential benefits of increased renewable generation, renewable resources pose a challenge to transmission and distribution system operators because they are variable in nature: system operators cannot control when the sun shines or when the wind blows, and thus cannot control when these resources are producing electricity. With storage, wind and solar power can be

stored and discharged when needed. Renewable projects can be developed with storage to allow for faster acceptance of renewable technologies in the market.

- *Energy storage can increase efficiency of power generation, particularly in densely populated urban areas.*

  Much like automobiles operate most efficiently at a consistent 55 miles per hour, many power plants operate most efficiently at a constant rate of output. Increasing or decreasing that rate reduces the efficiency of the energy conversion during combustion. Energy storage will limit the amount of ramping required of conventional generators, and enable power plants to operate more efficiently at a more constant speed.

In addition, if deployed in New York, the Liquid Metal Battery will:

- Create jobs and opportunities for New Yorkers,
- Contribute to an environmentally sustainable future for New York State,
- Benefit system performance and operations, and
- Maximize New York State electric ratepayer value in the operation of the electric grid.

The pages that follow contain a short summary of LMBC's electricity storage solution. We are certainly happy to provide additional information to the New York Energy Highway Task Force or others in the State.

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Respondent Information

Company Overview

LMBC is an early-stage company working to commercialize a new battery technology that will transform grid-scale electricity storage. The technology is reliable and safe, and promises several key features which make it potentially ground-breaking in terms of cost and performance:

- **Long-lifespan:** Liquid electrodes offer a robust alternative to solid electrodes, avoiding common failure mechanisms of conventional batteries, such as electrode particle cracking and phase transformation.
- **Low-cost:** From its conception, the LMBC team has focused all of its development efforts on producing as low a cost and as flexible a storage solution as possible. We have conducted market and economic studies which reinforce our recognition of the cost and performance requirements for stationary storage applications. LMBC's all-liquid design enables simple assembly, low-cost manufacturing using inexpensive commercial grade materials.
- **Scalable design:** Large-format design builds upon knowledge from metals industry, promising to achieve economies of scale.
- **Flexible:** Our Liquid Metal Battery has the flexibility to provide energy to the grid in both long duration and quick-response applications.

We expect to have our first batteries deployed in the first quarter of 2014.

LMBC will Create Local Jobs

LMBC's motto is "globally serving local markets, built locally." That is, because the Liquid Metal Battery is relatively simple to manufacture, we anticipate utilizing a distributed partner based manufacturing network for the deployment of our systems. As such, we anticipate being able to work with manufacturers local to New York State to build hundreds of megawatts of Liquid Metal Batteries. This will increase manufacturing jobs in New York while also helping to make the State's electricity infrastructure cleaner and more efficient and reducing the cost of electricity in New York.

Origins

The Liquid Metal Battery was invented in the lab of Dr. Donald Sadoway, a professor at the Massachusetts Institute of Technology who was recently named one of Time Magazine's 100 Most Influential People in the World. The Liquid Metal Battery Project at MIT built upon Professor Sadoway's 40 years of experience working with extreme electrochemical processes, ranging from aluminum smelting, to molten oxide electrolysis for extracting oxygen from lunar regolith, to lithium-ion polymer batteries research. David Bradwell (now Senior VP Commercialization, CTO and co-founder of LMBC) played an instrumental role in advancing the technology while he completed an M.Eng degree,[1] a Ph.D degree,[2] and a one-year postdoctoral fellowship in Professor Sadoway's group at MIT. In 2010, Bradwell and Sadoway founded LMBC with the goal of commercializing the LMB.

[1] David J Bradwell, *Technical and Economic Feasibility of a High Amperage Energy Storage Device*, Masters of Engineering Thesis, Massachusetts Institute of Technology, Advisor: Professor Donald R Sadoway Sept. 2006

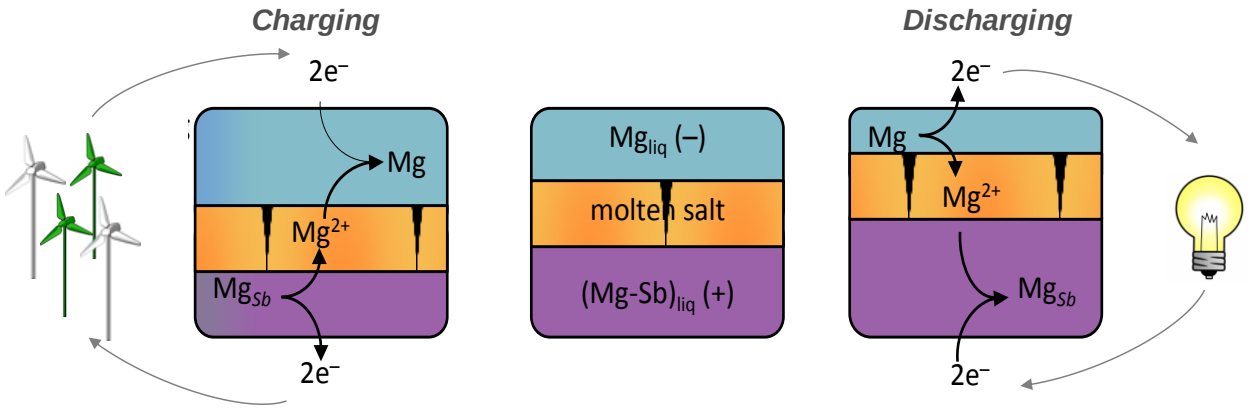
[2] David J Bradwell, *Liquid Metal Batteries: Ambipolar Electrolysis and Alkaline Electroalloying Cells*, Doctorate of Philosophy, Massachusetts Institute of Technology, Advisor: Professor Donald R Sadoway, Sept. 2010

Since LMBC was founded in 2010, the team has made significant technical progress. The project began at MIT where one amp-hour liquid metal batteries were developed and cycled. Now, LMBC is developing and operating 1000-amp-hour cells. The next step is to optimize the operation of these cells and stack the cells into modules before finally placing the modules into 40' shipping containers.

Technology

The Liquid Metal Battery consists of three liquid layers of molten metal that self-segregate, floating on top of each other based on density differences and immiscibility. The result is a robust system that is has a long lifespan, uses low-cost materials, and is easy to assemble. One of the early chemistries investigated was based on magnesium and antimony as the negative and positive electrodes, respectively, and a low cost molten salt ($MgCl_2$-KCl-$CaCl_2$) electrolyte. Since then, higher voltage and lower cost chemistries have been discovered and are being pursued at LMBC.

The system operates at elevated temperatures (~500 °C). Cells are able to 'self-heat' by utilizing heat generated in charging and discharging cycles, enabling high operating efficiencies in commercial system (~$1m^3$) sizes. At smaller scale, cells are kept hot in furnaces, allowing researchers to evaluate electrical performance and predict performance at larger scale.



Fundamentals of the Liquid Metal Battery: All three main components of the battery are liquid and self-segregate, enabling use of low-cost components that are easy to assemble and will last for a long time.

The unit cell technology has been consistently demonstrated at small (1" diameter, 1Ah cell) and medium (4" diameter, 20Ah cell) sizes, and LMBC seeks to increase the cell size to large scales (16"x16" square cells, 1000-1300Ah). LMBC will develop the large-scale cells, produce stacks of cells, and package stacks together in self-contained and fully-functioning modules. The estimated size of a self-contained and fully-functioning module is 1 m deep x 1 m wide x 2 m tall. A string of 20 modules, requiring the footprint of a 40' shipping container, will have an output power of 0.5 MW / 2 MWh with 4 hours of discharge capacity at the rated power.

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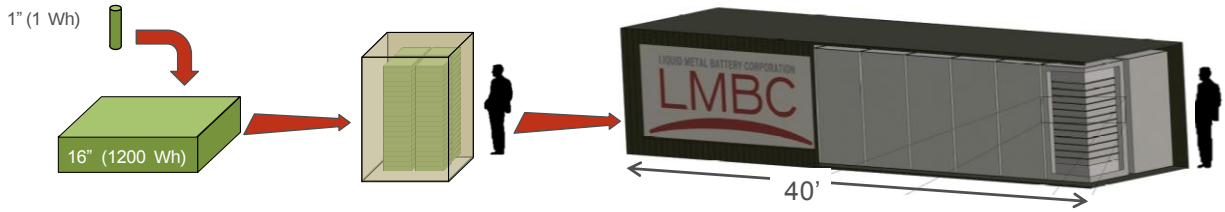
Cell
Scale 1 Wh to > 1200 Wh

Module
25 kW (100 kWh)

System
0.5 MW (2 MWh)



Conceptual design of LMBC's energy storage solution, representing 0.5 MW / 2 MWh of capacity in the footprint of a 40' shipping container.