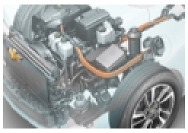
Low-Cost Electric Vehicle Batteries That Do Not Need a Heavy Protective Box | Grigorii Soloveichik, ARPA-E with Julian Sculley and Aron Newman, Booz Allen Hamilton



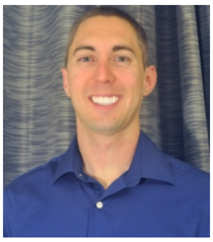
ARPA-E's RANGE[1] (Robust Affordable Next Generation Energy Storage Systems) program funded high-risk research projects to change the way electric vehicle battery systems are built.

The program is a success both in terms of individual projects and in reshaping the paradigm about energy storage as a whole to include system-level considerations. This was accomplished by setting very aggressive program metrics, by pushing the teams to advance their technology toward commercialization (through active program management), and by all of the effort the teams invested.

Grigorii Soloveichik, Program Director, Advanced Research Projects Agency-Energy, United States Department of Energy, ARPA-E

Decarbonizing the transportation sector remains a significant hurdle as the world begins to transition away from fossil fuels. Highly efficient Electric Vehicles (EVs) are gaining market share, but have been hampered by anxiety over range and battery safety[2]. To assuage these fears, battery producers and automakers are working together to create safe, higher-energy-density batteries that require adding layers of protection, e.g. a strong (and heavy) metal box. So far, the majority of research has focused on developing redox couples that have higher energy density than current Li-ion batteries (LIB). The underlying approach to improving LIBs revolves around increasing energy density to reduce the cost per cell, while lowering the battery pack mass, thus increasing driving range (mile/kWh). However, one potential limitation to this approach is that higher energy density LIBs will generate a more energetic response when abused or impacted. This requires increased safety protection at the pack- and system-level, including impact shielding, which negates the gains. The same effects apply to system-level costs, which must be kept low to increase EV deployment.

Central to ARPA-E's mission is the mantra, ?If it works, will it matter?? which we use define a program's metrics accordingly. The RANGE program metrics are: pack-level cost <$125/kWh, >150 Wh/kg and >230 Wh/L, passing of USABC battery mechanical abuse tests, and not undergoing thermal runaway while being crushed[3].



Julian Sculley, Science Engineering and Technology Advisor, Support contractor for ARPA-E, Booz Allen Hamilton

The approach to battery development followed the principles of safety by design (fragmentable cell electrodes and compartmentalized cells embedded in a matrix that can absorb heat and impact) and safety by chemistry (using aqueous chemistries or solid electrolytes with high energy density anodes, such as lithium metal encapsulation and/or protection). Applying multiple design principles to the system design should lead to extremely low-cost chemistries based on abundant materials, multifunctional design to reduce the system mass, thereby increasing mile/kWh, and lower pack overhead due to higher system robustness (Figure 1).

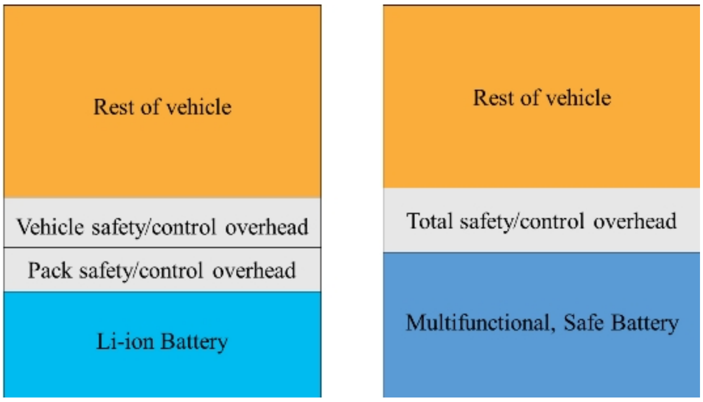


fig.1: A schematic comparison of weight distribution of EVs with conventional (left) and RANGE (right) batteries. Despite the great difference in battery weight, the two vehicles may have the same Wh/kg-vehicle and range?. | Source: ARPA-E

Aron Newman, Science Engineering and Technology Advisor, Support contractor for ARPA-E, Booz Allen Hamilton

The RANGE projects fell into a few general categories: aqueous and solid state electrolytes, structural or multifunctional Li-ion batteries, and methods of preventing cascading thermal runaway. The projects highlighted below are representative of successful projects in the RANGE portfolio.

One project led by the University of Maryland (»Link) is developing aqueous electrolytes that are able to operate above the water splitting voltage, the historical limit. In this case, a series of improvements were made to the electrolyte composition to enable a larger voltage stability window (>3V), which led to high energy densities comparable with conventional LIBs.

In another project from University of Maryland (»Link), advances in garnet-based solid electrolytes are leveraged to develop Li metal batteries with sulfur or metal oxide cathodes. The team has been able to build a scalable and reproducible process to fabricate multilayer garnet structures with a thin, dense central layer on high-surface-area porous supports that accommodate Li deposition. This battery contains no flammable electrolyte and should be less expensive thanks to the possibility of a smaller fire suppression system. With this design, the cell capacity can be increased and has the potential of having significantly longer cycle life.

The project team led by Stanford University (»Link) is building a battery pack that can be used as a structural component in a vehicle. If the battery can become a load-bearing structure, then less material is needed to build the EV, thus reducing total vehicle mass and leading to higher miles/kWh. The battery pack is composed of perforated electrodes that are held together with polymer rivets and carbon-fiber/epoxy blended face sheets. The resulting construction acts as a structural beam while retaining its primary function of energy storage.

Lastly, Cadenza Innovation (»Link) is a startup company developing a ?supercell? containing multiple Li-ion jelly rolls that are embedded in a ceramic housing to prevent cascading thermal runaway. The simple design and pack architecture enable low-cost and high-yield manufacturing processes. The novelty of the project lies in the non-combustible ceramic housing material that allows closer packing of high-energy--density cells and pack-level savings from an open can structure with a shared atmosphere and less redundancy. In conclusion, the RANGE program has developed an array of inherently robust battery chemistries and architectures that will impact EV system-level design.

Notes:

[1]The Advanced Research Projects Agency-Energy (ARPA-E) invests in transformational ideas to create America's future energy technologies. ARPA-E focuses exclusively on early stage technologies that could fundamentally change the way we generate, use, and store energy. RANGE stands for Robust Affordable Next Generation Energy Storage Systems.
[2]J. Bartlett, Survey: Consumers express concerns about electric, plug-in hybrid cars, »Link, Accessed March 3, 2014.
[3]to 50% of the original dimensions or being subjected to a force of 1000 times of battery mass. For full details, see RANGE funding opportunity announcement at https://arpa-e-foa.energy.gov.
?Liu, P., Ross, R. and Newman, A., 2015. Long-range, low-cost electric vehicles enabled by robust energy storage. MRS Energy & Sustainability, 2, p.E12.

Grigorii Soloveichik,
Program Director, Advanced Research Projects Agency-Energy, United States Department of Energy,

ARPA-E

Julian Sculley,
Science Engineering and Technology Advisor, Support contractor for ARPA-E,
Booz Allen Hamilton

Aron Newman
Science Engineering and Technology Advisor, Support contractor for ARPA-E,
Booz Allen Hamilton

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