An Update on the U.S.-China Bi-lateral EVI Agreement

美中电动汽车草案双边协议更新

presented at the
6th China-U.S. Electric Vehicle and Battery Technology Workshop

University of Massachusetts Boston
August 23, 2012

Larry Johnson, Ph.D., Director
Transportation Technology R&D Center
Argonne National Laboratory

Workshops occur twice a year, alternating between the US and China
研讨会每年两次，美中两国轮流主办

- **Sponsored by:**
  - U.S. Department of Energy
  - China's Ministry of Science and Technology
- **Six workshops**
  - Beijing — September 2009 Electric Vehicle Forum
  - Argonne — August 2010
  - Beijing — March 2011
  - Argonne — August 2011
  - Hangzhou — April 2012
  - Boston — August 2012

- **Three focus areas**
  - Battery Technology Roadmapping
  - Battery Test Procedures
  - Vehicle Demonstrations and Infrastructure

This workshop has broad speaker participation
本次研讨会吸引了来自广泛领域的演讲者

United States

- American National Standards Institute
- Argonne National Laboratory
- BASF
- Ford Motor Company
- Idaho National Laboratory
- Lawrence Berkeley National Laboratory
- Massachusetts Institute of Technology
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory
- Power Genix
- SAE International
- University of Massachusetts, Boston
- U.S. Department of Energy

17 Presenters

China

- Beijing Institute of Technology
- China Automotive Engineering Research Institute
- China Automotive Technology And Research Center
- Lishen Battery Company
- Shanghai International Auto City
- Shanghai Jiaotong University
- Tsinghua University

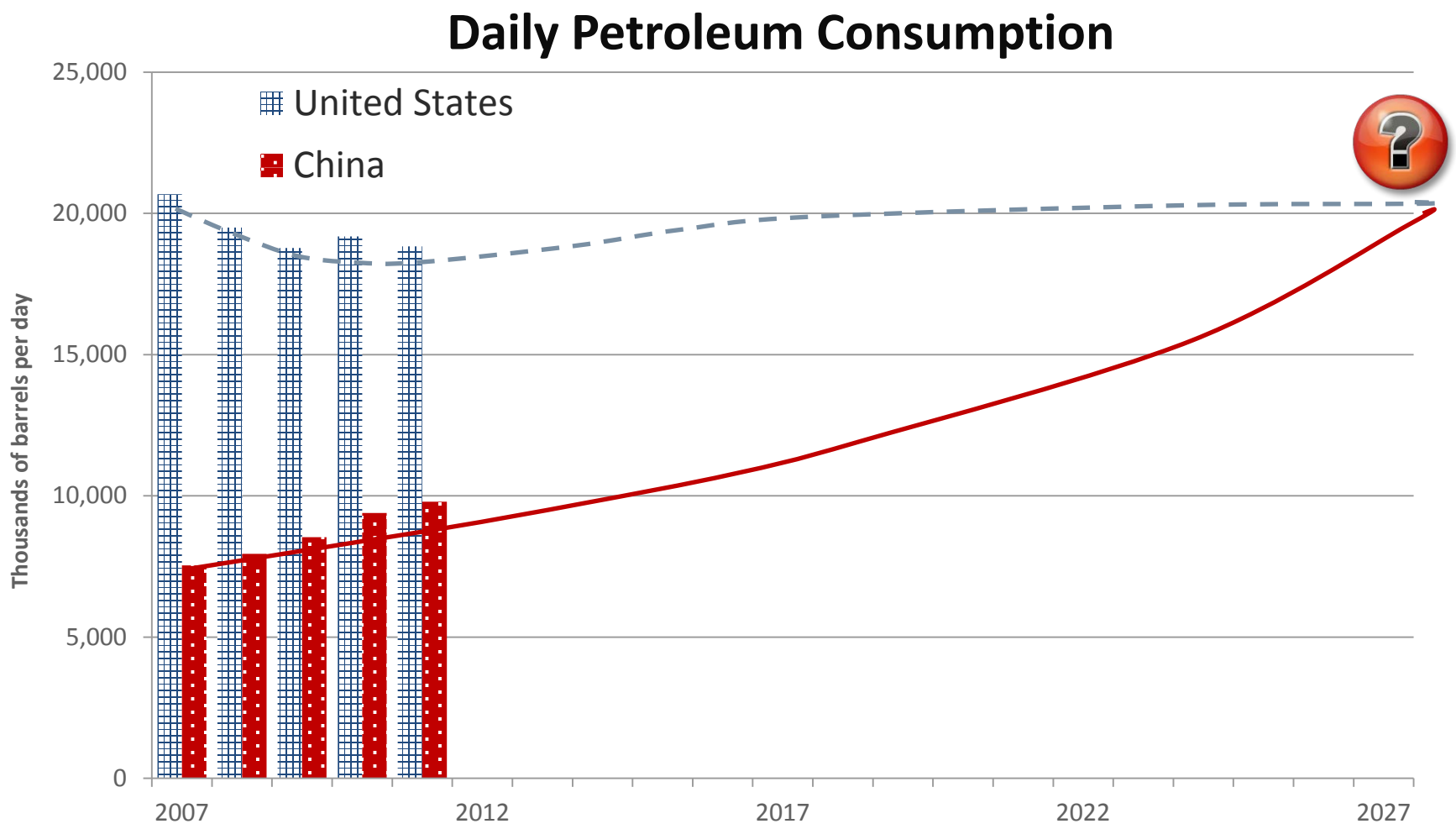
15 Presenters

The focus of the bi-lateral EVI is non-proprietary research
EVI双边协议的重点是发展非专利研究

- **Topics presented at this workshop**

– Research overviews	4
– Lithium air chemistries	5
– Other battery chemistries	5
– Battery materials	5
– Battery swapping	1
– Battery recycling	1
– Battery testing	2
– Vehicle testing	2
– Vehicle demonstrations	3
– Standards	4
– Total	32

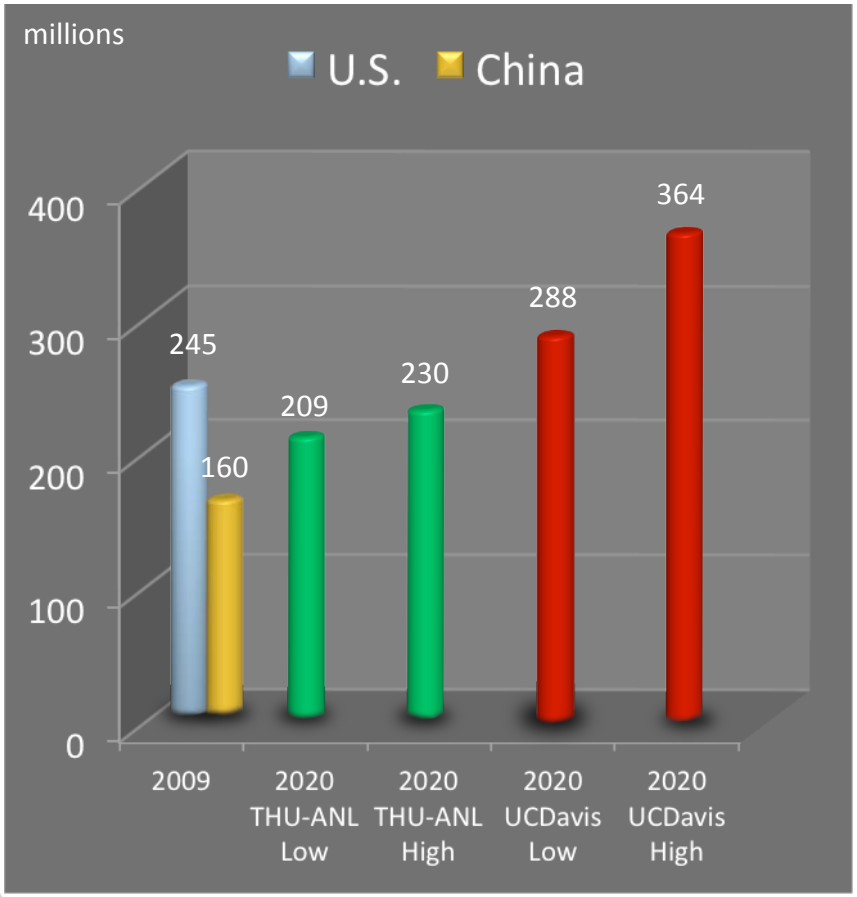
US and China: two largest vehicle markets and oil users
美国和中国：两个最大的车辆市场和原油使用者

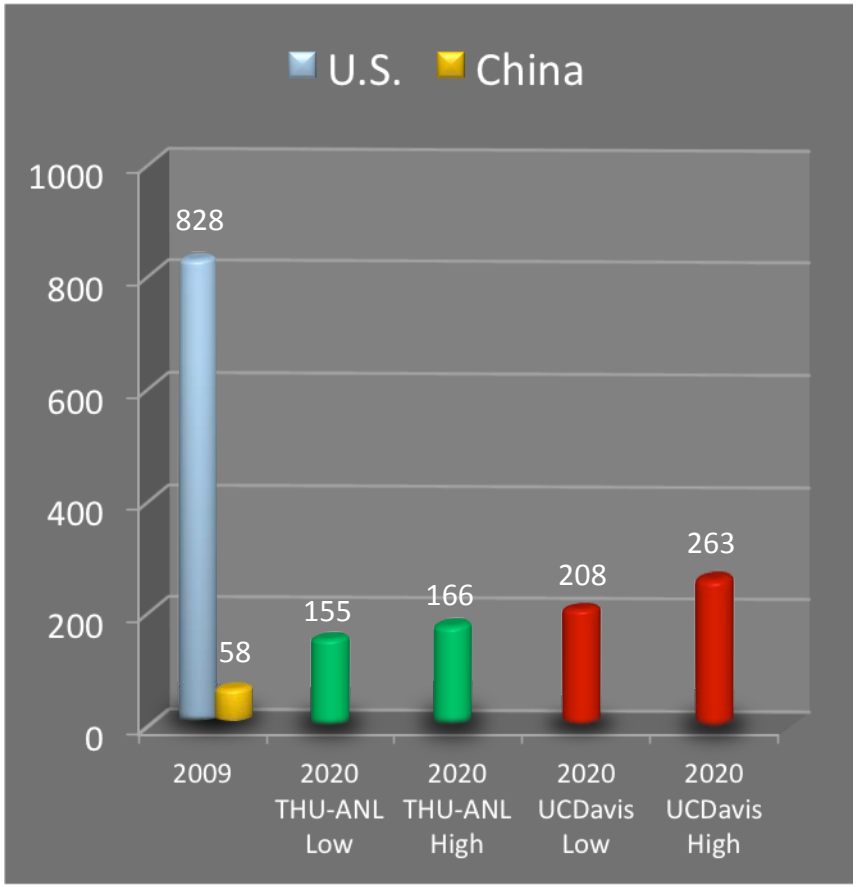


Source: Historical data: US Energy Information Administration (http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=5&aid=2)

Projections of vehicle stock show rapid growth
车辆保有量的预测显示快速增长

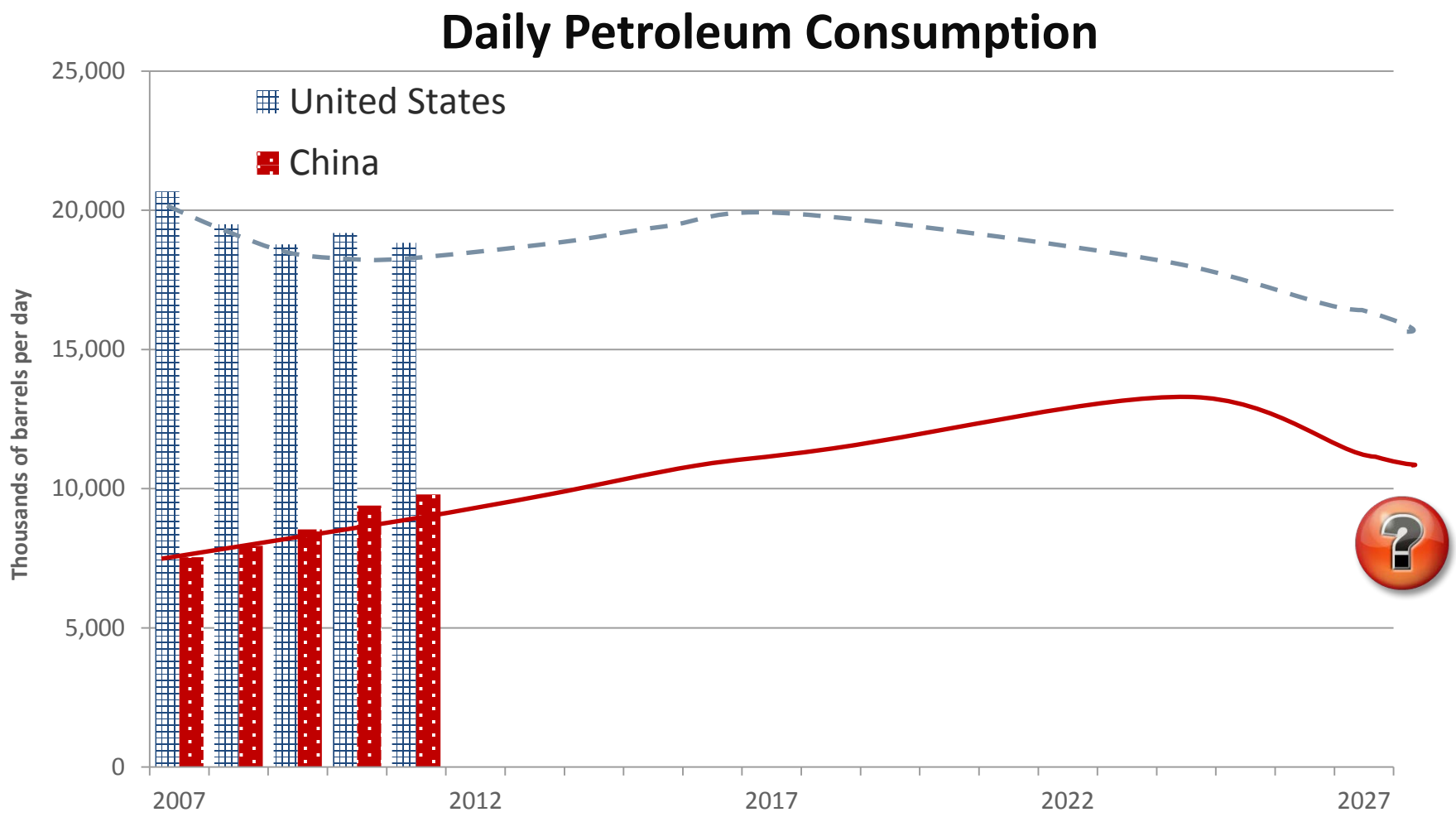
But motorization rates are still relatively low
但是机动车率仍相对较低





Can the future look like this?
未来可以是这样的吗？

Yes, if we make history.
可以，如果我们创造历史。



Source: Historical data: US Energy Information Administration (http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=5&aid=2)

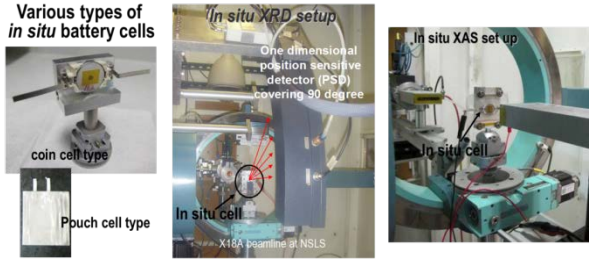
Battery Technology Action Plan: 电池技术发展规划：

Co-leaders (主席) **Dave Howell – U.S. Department of Energy 美国能源部**
WU Feng – Beijing Institute of Technology 北京理工大学

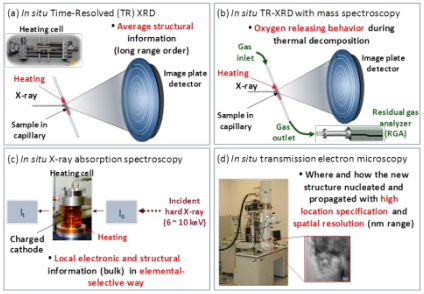
- **Scope of the Collaboration 合作范畴**
  - Conduct pre-competitive research on advanced battery technologies
  - Identify practical and cost-effective battery recycling processes
- **Goals / Objectives 目标与目的**
  - Targeted technologies include: lithium air, lithium sulfur, lithium metal
- **Desired Results 预期结果**
  - Characterization of next-generation of lithium-ion batteries
  - Identification of relevant, advanced facilities in the U.S. and China
  - Evaluation of existing diagnostic tools
  - Design /conduct experiments for various battery chemistries

New *in situ* diagnostic techniques developed at BNL
布鲁克海文国家实验室开发的新诊断技术

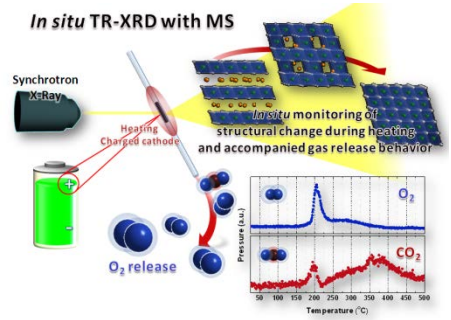
- **Collaborations**: Institute of Physics, Tsinghua University, Beijing Institute of Technology
- **Facilities**:
  - National Synchrotron Light Source
  - Center for Functional Nanomaterials
- A combination of in situ XRD and XAS used to study local- and electronic- structure changes in lithium battery materials in a coin cell during charge-discharge cycling.



- The structural origin of thermal instability of cathode materials, a critical safety issue for lithium-ion batteries has been studied systematically using suite of various in situ synchrotron X-ray techniques and TEM

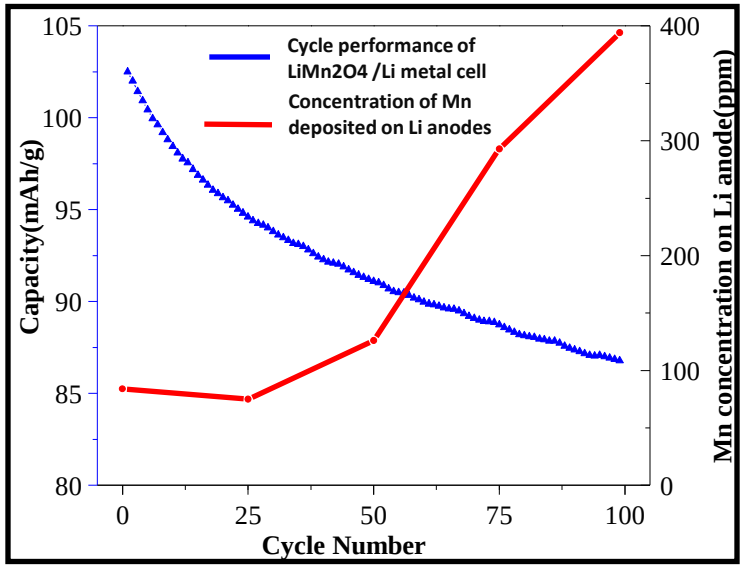


- Cathode samples harvested from charged cells are heated to 500°C and XRD patterns and MS data collected and correlated to structural changes. Important for improving thermal stability



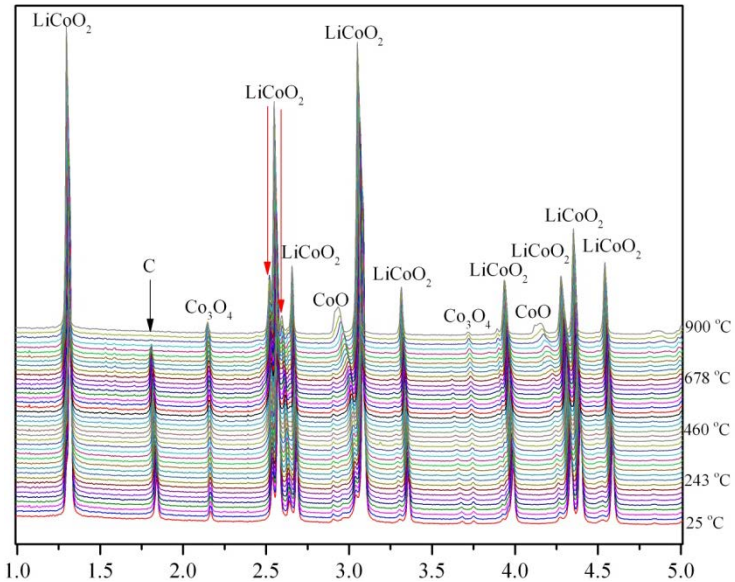
Understanding how Mn-dissolution affects LMO systems
阿岗-清华共同研究锰溶解如何影响锂锰氧电池性能

- **Capacity fade in LMO-based full cell**
  - LMO is an important chemistry – used in the cathode in both the Volt and Leaf
  - Capacity fade is a key problem for spinel $LiMn_2O_4$/carbon cells
  - Capacity is related to the amount of lithium removed from the cathode
  - Need to understand details of what is happening and why:
    - At the LMO cathode
    - At the lithiated-graphite anode
  - Lab experiments show significant capacity fade after only 100 cycles when using Li and carbon anodes
    - Leading to better understanding of the correlation between manganese dissolution, migration and deposition (DMD) process and capacity fading in LMO-based lithium ion batteries
    - Shedding some light on how to improve the cell performance.
- **Collaboration:**
  - Argonne: Khal Amine, Jun Lu
  - Tsinghua: Qiu Xinping
    + Chun Zhan, Ph.D. student
- **X-ray absorption techniques**
  - EXAFS: helps to understand MN compounds deposited on the anode
  - XANES: helps to understand oxidation state changes at the LMO cathode
- **X-ray Photoelectron Spectroscopy** (XPS)
  - Helps to identify and understand electrode surface components and interactions



Recovery of cobalt and lithium from spent Li-ion batteries
从废锂离子电池回收钴和锂

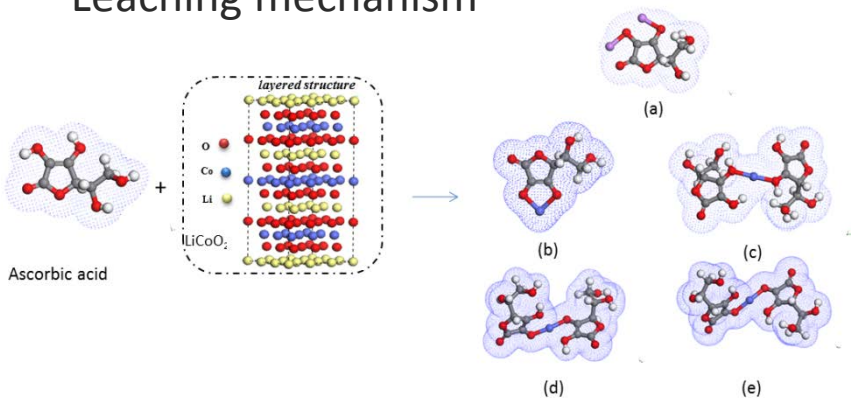
- **Collaboration:**
  - Argonne: Khal Amine, Jun Lu
  - BIT: Feng Wu, LiLi
- **In-situ X-ray diffraction technique at APS**



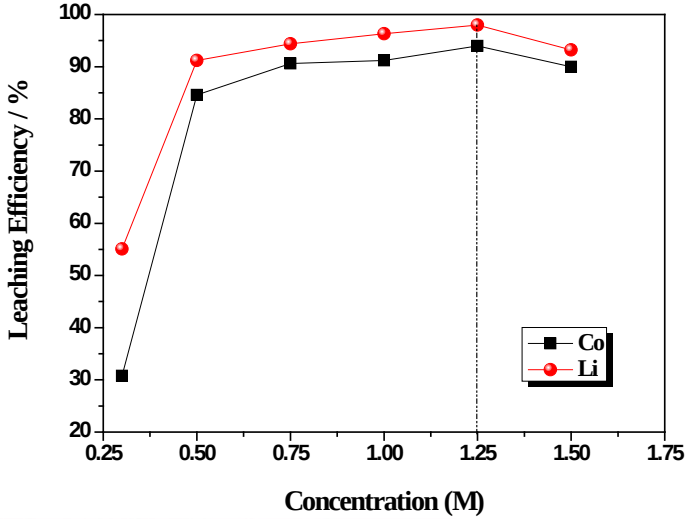
- **In-situ XRD patterns of the samples during heat treatment**

Li Li, Jun Lu, Yang Ren, Xiao Xiao Zhang, Ren Jie Chen, Feng Wu, Khalil Amine *Journal of Power Sources, Volume 218, 15 November 2012, Pages 21-27*

Leaching mechanism

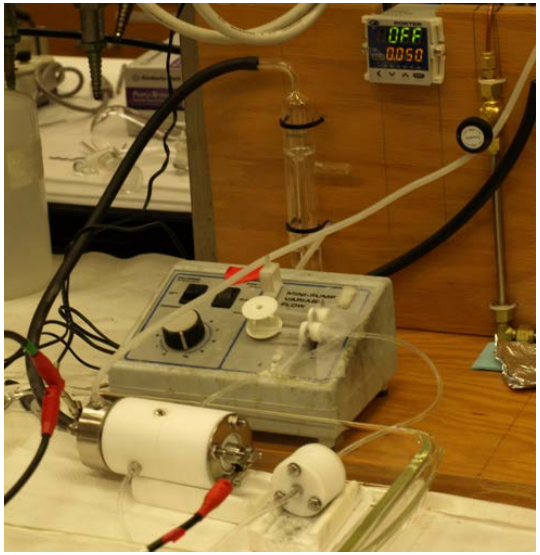


Leaching efficiency as function of ascorbic acid concentration



Reaping the benefits of Li-air requires overcoming major obstacles
充分发挥锂空气电池的优势而需要克服的主要障碍

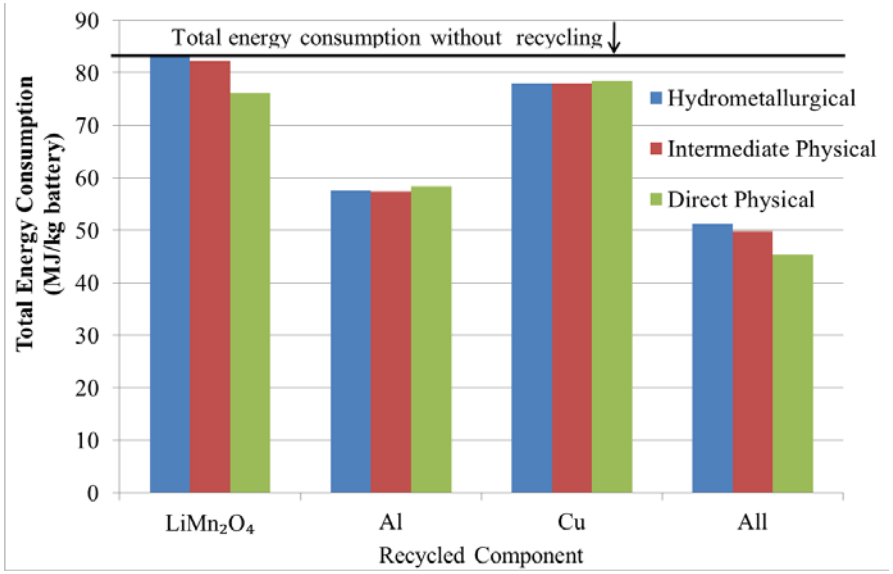
- **Challenges:**
  - Rechargeability and safety of metallic Li anode.
  - Solid products of oxygen reduction in in the non-aqueous electrolyte will remain in the pores of the porous electrolyte, and eventually will fill up all the pores and passivate the oxygen cathode.
  - The solubility and diffusibility of oxygen in a non-aqueous electrolyte is low.
  - Electrolytes are consumed during battery operation.
- **UMass Boston is focused on oxygen cathode**
  - Additives and electrolytes are developed to enhance the solubility and diffusion rate of oxygen, the discharge rate was increased to 10 mA/cm2.
  - An catalyst was found to substantially increase the disproportionation rate of superoxide (O2-), thus the interaction between superoxide and electrolyte is alleviated.
  - A unique flow cell was designed to minimize the electrolyte blocking.
- **Partner:** Brookhaven National Laboratory
- **Collaborators:** Pacific Northwest National Laboratory
  Beijing Institute of Technology
  Tsinghua University



Lifecycle analysis of metal recovery from Li batteries
锂电池金属废物回收

- **Goal**: Compare BIT leaching process to other recycling processes via LCA
  - BIT provided experimental data
  - ANL conducted LCA
  - Papers* written on BIT process and comparison
- **Processes compared**:
  - BIT leaching process with citric acid in presence of H_2O_2
  - Intermediate physical process
  - Direct physical recovery
- **Conclusion:**
  - Similar energy savings for all processes
  - Energy savings increase as more materials are recovered

Combined recovery of active and structural materials optimizes energy benefits of recycling



** Joint paper: Recovery of Metals from Spent Lithium-ion Batteries with Organic Acids as Leaching Reagents and Environmental Assessment;* L. Li, J. B. Dunn, X. X. Zhang, L. Gaines, F. Wu, R. J. Chen

Argonne paper: The Impact of Recycling on Cradle-to-Gate Energy Consumption and Greenhouse Gas Emissions of Automotive Lithium-Ion Batteries, J. B. Dunn, L. Gaines, J. Sullivan, M. Q. Wang

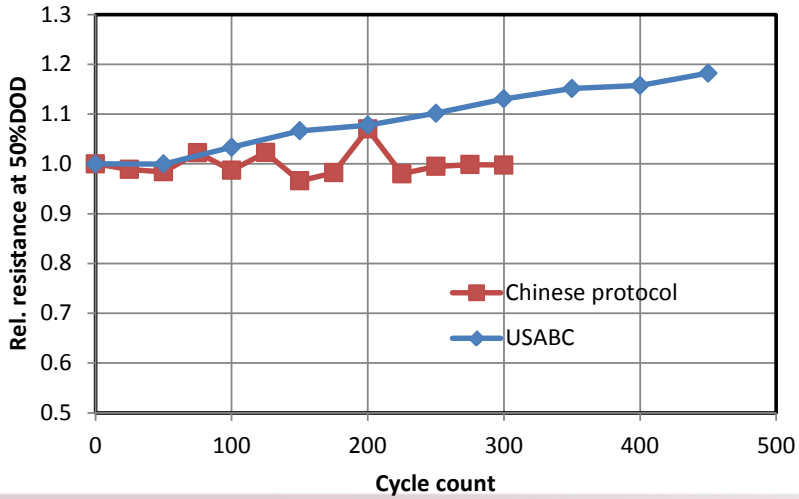
Battery Testing Action Plan:电池测试程序:

Co-leaders (主席) Ira Bloom – Argonne 阿岗国家实验室
QIU Xinping – Tsinghua University 清华大学

- **Scope of the Collaboration 合作范畴**
  - Direct experimental comparison of battery testing protocols from China & US
  - Complete failure analysis of cells; mapping of failure modes
- **Goals / Objectives 目标与目的**
  - Performance and Life
    - Identify similarities/differences in test philosophy, requirements, methods, etc.
    - Comparison of test results on the same batteries for quality / reproducibility
  - Safety
    - Identify potential hazards of the products of battery failure under given conditions
    - Identify / develop potential sensors, as well as potential extinguishing materials
- **Desired Results 预期结果**
  - Performance and Life:
    - Joint publication comparing test procedures and results
    - Share-able database and development of common protocols
  - Safety
    - Database of products produced during a battery failure / breech
    - Development of standards for testing internal short circuits
    - Development of testing standards for other battery issues (over temp, over charge, crush)

Battery Testing Protocols– Performance and Life
电池测试程序-性能和寿命

- **Test plan for** an EV application agreed to.
  - Commercially-available batteries based on $LiFePO_4$ and carbon were procured.
  - The batteries were distributed to participants.
  - All participants will use both sets of test protocols on the batteries in common
- **Actual experiments:**
  - Initial results show that the rate of battery performance change depends on the protocol.
  - With the USABC test results, the cells tested at ANL show a definite decrease in performance; power has decreased and resistance has increased (~13% increase in resistance at 50% DOD after 300 cycles). Capacity also decreased.
  - The data from CATARC shows, essentially, no change in power and resistance, but a significant change in cell capacity.



These results will be compared to those obtained at CATARC. Significant differences and root causes will be identified and resolved

Demonstrations / Standards Action Plan:示范与标准化：

Co-leaders (主席) **Keith Hardy – Argonne 美国能源部**
Li Jianqiu – Tsinghua University 清华大学

- **Scope of the Collaboration**

Learning together … how to deploy EVs that meet the needs of the public and the auto industry while minimizing the impact on national grids and the environment

- Share technical information and experience from **vehicle/infrastructure learning demonstrations** [share data from Shanghai and Los Angeles vehicle demos]
- Harmonize global **codes and standards** (vehicles, connectors, and communication) [share data and experience: map U.S. and Chinese standards; understand differences]
- Harmonize **vehicle benchmarking**, evaluating, and testing procedures [exchange information on vehicle test procedures; harmonize if possible]

- **Goals / Objectives**

- Understanding use patterns of electric vehicles and the charging infrastructure to guide vehicle technology development and deployment of EVSEs
- Codes and Standards: harmonization of grid connectivity standards
- Vehicle Testing: harmonize benchmarking and test procedures where possible

EV demos help guide technology and EVSE deployment
电动汽车展示有助于技术指导和电动汽车设备的发展

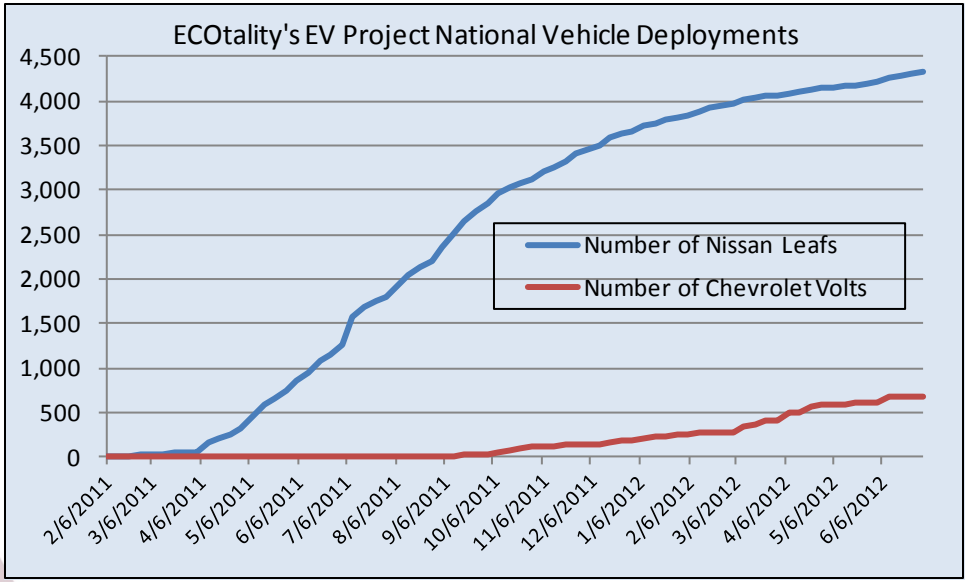
Total US Results* – as of May 2012

- 4,998 Leafs and Volts deployed and reporting data
- 6,319 EVSE installed and reporting data
- 32.9 million miles driven
- 881,000 charging events

LA Results* – as of May 2012

- 488 Leafs and Volts deployed and reporting data
- 528 EVSE installed and reporting data
- 2.9 million miles driven
- 69,000 charging events

*** Data collected by the Idaho National Laboratory from ECOtality's EV Project**



Volt Charging at an EV Project Level 2 EVSE

EV Demonstration: urban transport in transition
电动汽车示范：为城市交通电动化转型服务

Data Analysis: Oct 2011 – Jun 2012

- Visitors: **35,745**
- Test drivers and riders: **14,137**
- Total mileage: **127,977** km (8 cars)
- Surveys completed: **2,285**
- Cars sold: **25**, Advance Booking: **97**

EV International Pilot City
New Energy Vehicle Demonstration
Operation Annual Report

CPC,
Beijing-Test Drive

International
Demonstration

The Demonstration Environment

- AC Poles :**98** DC Poles :**5**
- Exchange Station :**1** Hydrogen Station **1**
- Safety and maintenance guarantee for new energy battery electric passenger car demonstration operating on roads
- Emergency rescue training With GM
- Party School of The CPC, Beijing Test Drive and Test Ride Centre

International Demonstration

- Model Vehicles: GM Volt, Coda EV ,Volvo C30 ,Toyota Prius ,Nissan Leaf
- Shanghai-LA EV Demonstration Data Sharing
- China-U.S. EV Demonstration – joint research UC Davis

Lack of harmony in codes and standards increases costs
缺少法规和标准会增加成本

- **Interoperability**
  - Capability of different systems and devices to communicate and operate effectively with one another
  - A barrier to widespread adoption of EVs is the interoperability of charging interfaces.
  - Interoperability compliance ensures that any car can be charged from any corresponding charger.
- **Relevant Stakeholders**
  - American National Standards Institute Electric Vehicle Standards Panel (ANSI EVSP)
  - Society of Automotive Engineers (SAE International), International Electro-technical Commission (IEC)
  - NIST Smart Grid Interoperability Task Force
  - NIST Office of Weights and Measures
  - Smart Grid Interoperability Panel (SGIP)
- **SGIP Vehicle-to-Grid**
  - Domain experts identify and address standardization priorities;
  - Catalog of Standards includes SAE J1772, J2836/1 & J2847/1.
    - Under review: SAE J1772-2012, J2836/2, J2847/2, J2931/1 & 2894/1
- **International Cooperation**
  - Invite formal collaboration through Letter of intent (LOI) with international entities.
  - SGIP Agreements with
    - Korea Smart Grid Standardization Forum
    - European Union Smart Grid Coordination Group
    - Japan Ministry of Economy, Trade and Industry
    - SGIP to approach CATARC and CAERI on collaboration

Vehicle Testing: collaboration and data sharing
车辆测试：合作和数据共享

Goal:

- Develop common procedures to test advanced vehicles in China and the U.S.
- Link test engineers from both countries to develop procedures and gathering test data

Desired Results:

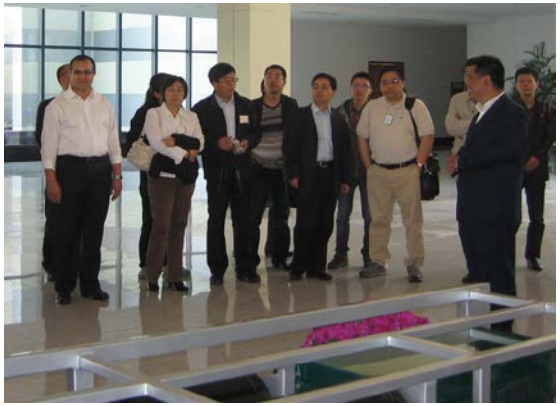
- Procedures developed in both countries designed to be as harmonized as possible.
- Differences should be well-understood so that test data can be useful to both.
- Future data can then be shared between countries for mutual benefit.

Status:

- Plug-in Prius purchased by CAERI and at Argonne for initial benchmarking
- Argonne to host two CAERI engineers
- After 6 months, vehicle to be shipped to CAERI for their tests

Action Items:

- Share documentation of all test procedures, e.g.: SAE J1711, J1634 and J2711)
- Share test data used in procedure development and validation
- Attend workshops to discuss and resolve issues, share data, methods
- Site visits to review procedures, methods, instrumentation hardware, vehicles

Scenes from the workshop in Hangzhou: April 16 – 17
在杭州举行的研讨会照片：2012年4月16 – 17

Thank you
谢谢