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清华-伯克利深圳学院  
Tsinghua-Berkeley Shenzhen Institute

# Digital Battery Passport: Towards a Sustainable and Smart Living

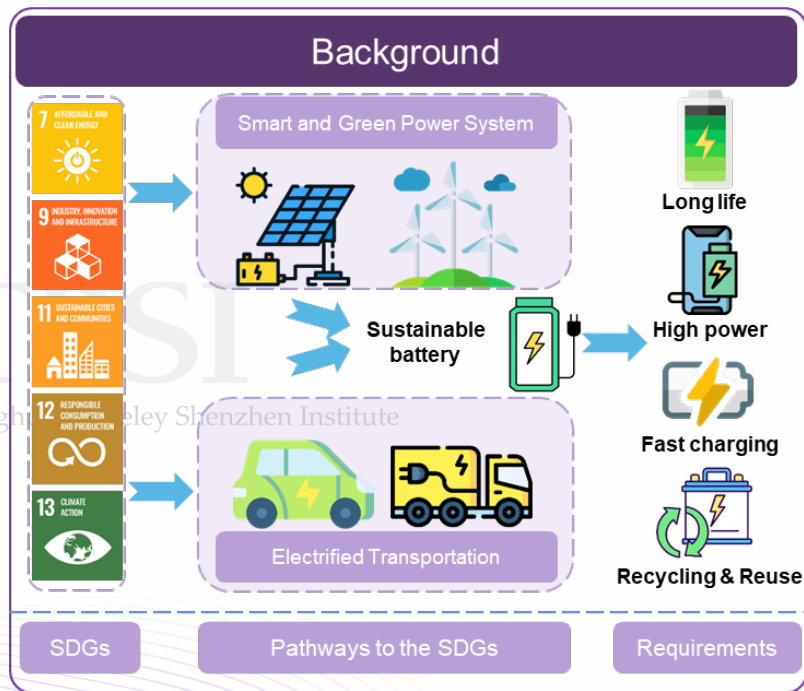
Shengyu Tao<sup>a</sup>, Zheng Liang<sup>a</sup>, Tao Shi<sup>b</sup>, Mengtian Zhang<sup>c</sup>, Daimeng Li<sup>a</sup>

<sup>a</sup>Lab 1C Smart Grid and Renewable Energy

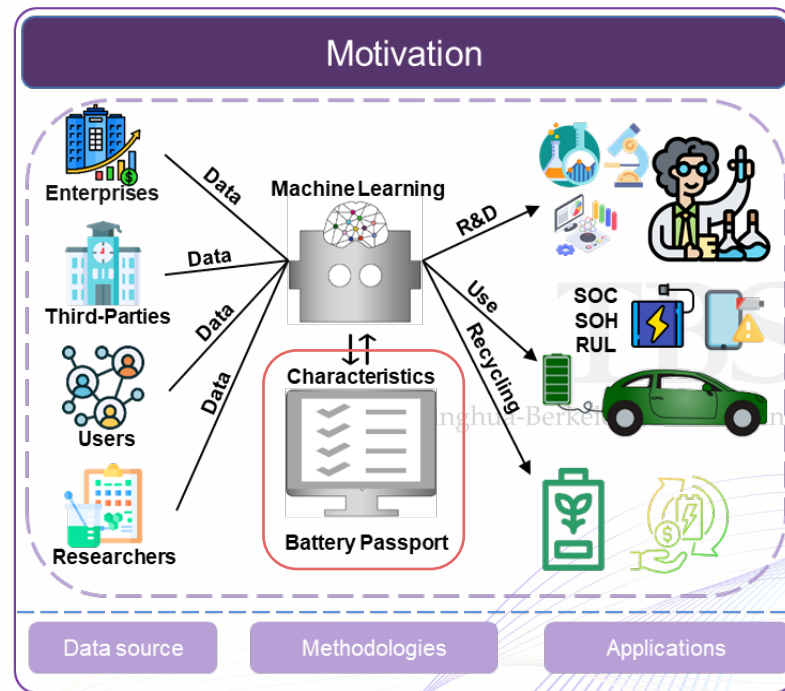
<sup>b</sup>Lab 2C Internet of Things and Societal Cyber Physical Systems

<sup>c</sup>Lab 1F Low-Dimensional Materials and Devices

7<sup>th</sup> July, 2023

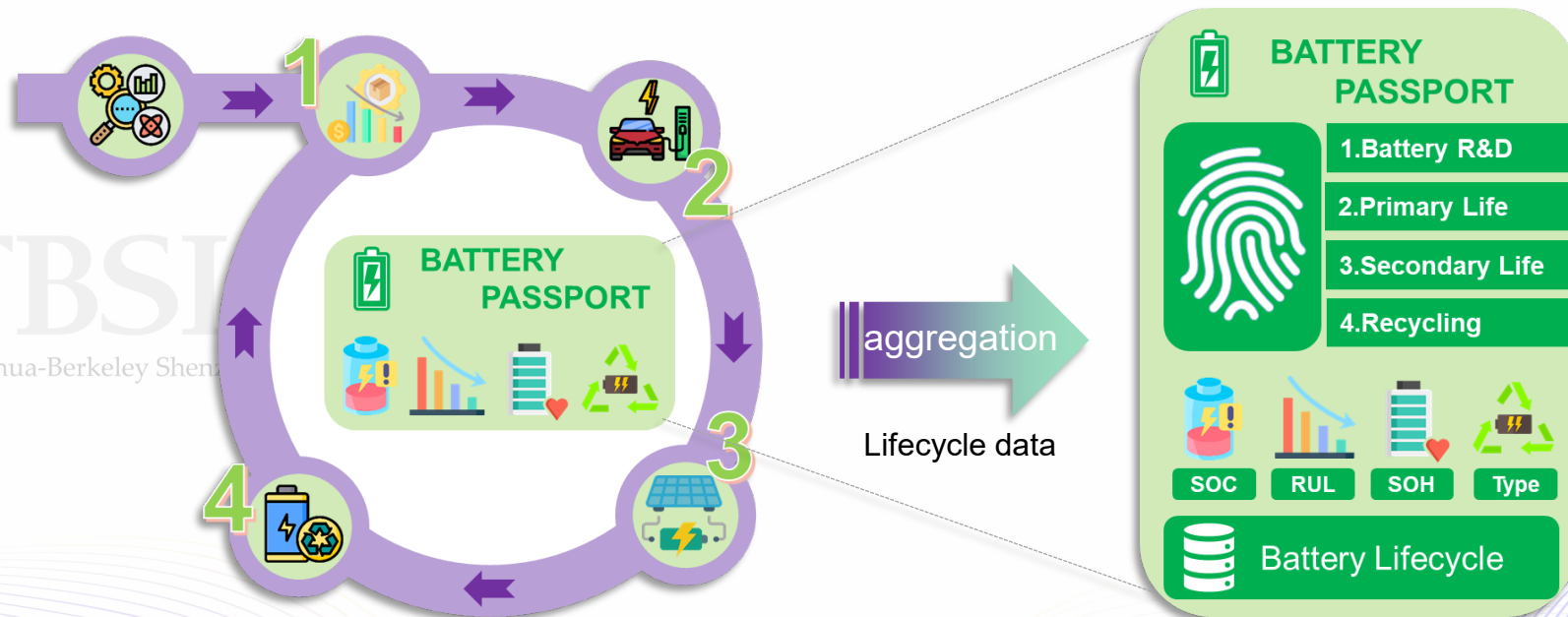


Battery empowers critical sustainable development goals (SDGs) while remains high requirements



Machine learning is promising in ensuring these requirements by leveraging data characteristics

The battery passport concept:



The battery lifecycle from prototype R&D, primary life, secondary life to battery material recycling

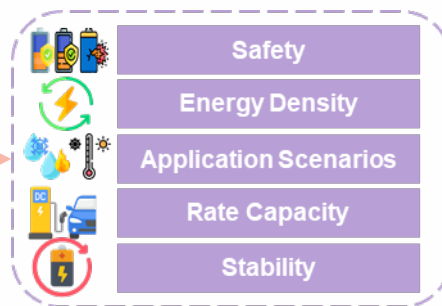
The battery passport, recording critical lifecycle data and highlighting different data characteristics

## Data characteristic

- High dimensional
- Large volume
- Multimodal

Microscopic characterizations

Material insights



Application requirements

Wighted harmonic mean

Battery F-score

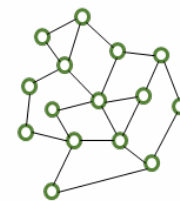
Long life Fast charging High power  
Application-Specific Labels

Electron spin orbitals  
Molecular orbitals

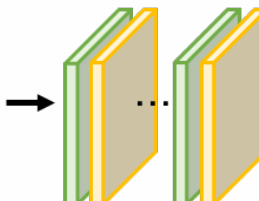
Band structure  
Crystal structure

Bond orientation  
Atomic energy

Dimension reduction



Graph Formulation



Convolution + Pooling Layers



Dense Layer



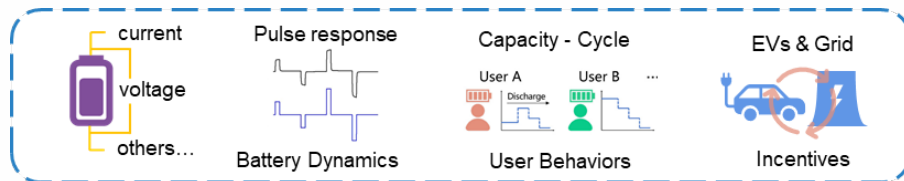
Softmax Layer

argmax

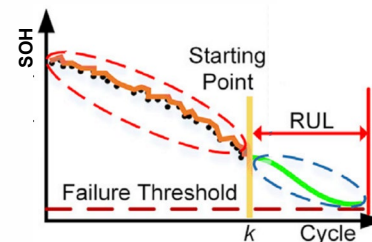
Predictions

Material information

Battery Graph Convolutional Neural Network (BatteryGCN)

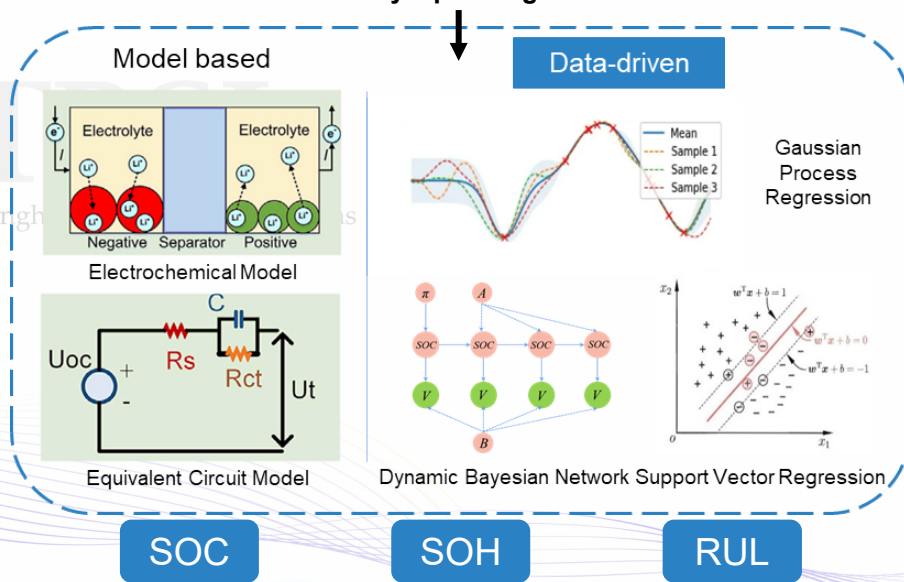


Battery Operating Data

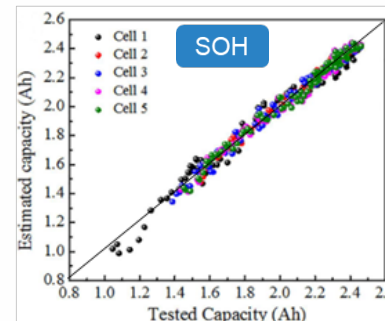


## Data characteristic

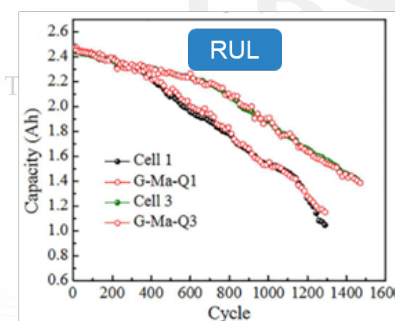
- Low dimensional
- Highly noisy
- Highly random



## Results of Gaussian Process Regression



10% cross validation:  
RMSE < 0.02, R2 > 98%



Estimation on cells:  
RMSE ~ 0.02, R2 > 99%

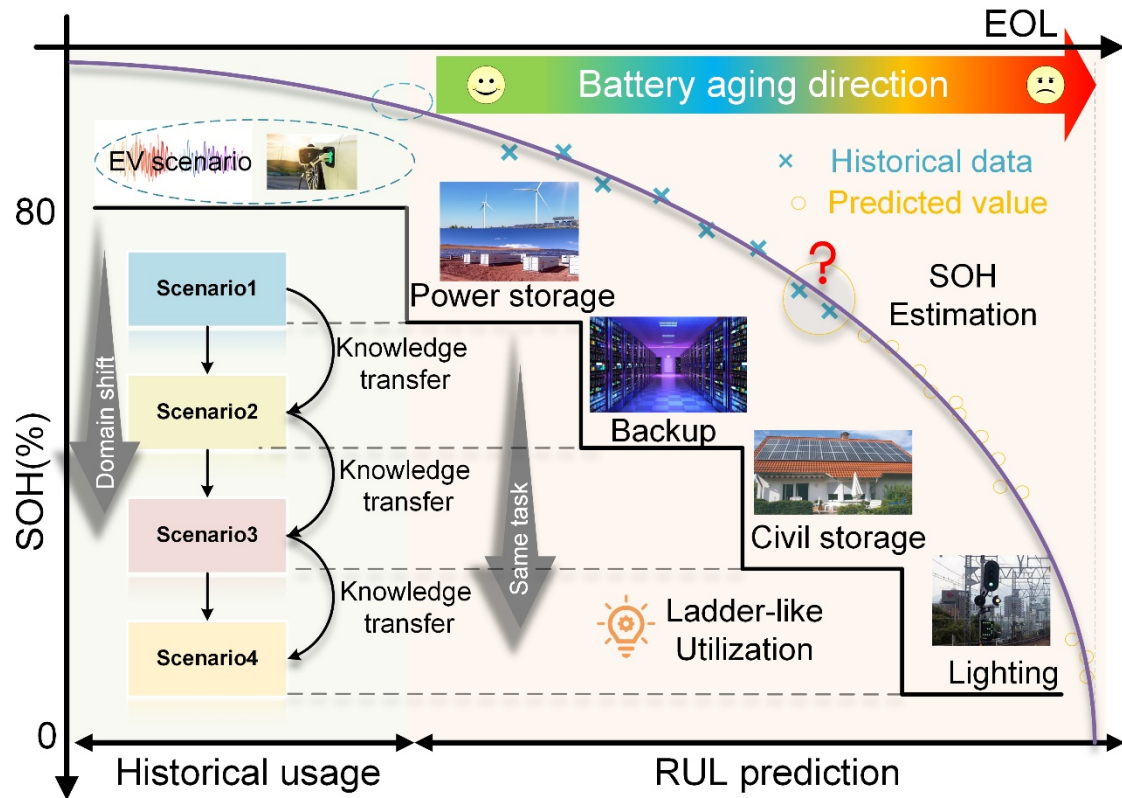
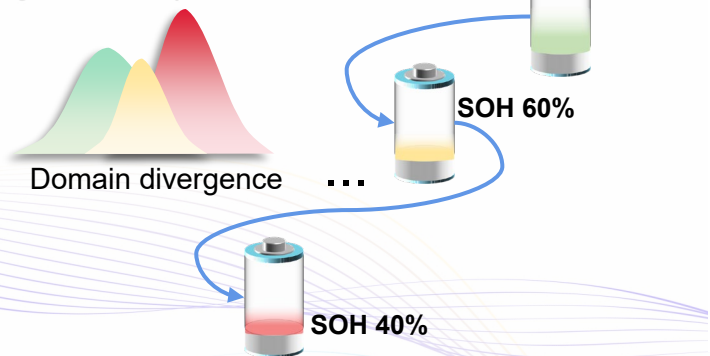


## Data characteristic

- Small volume
- Domain divergence
- Similar task

## Transfer learning

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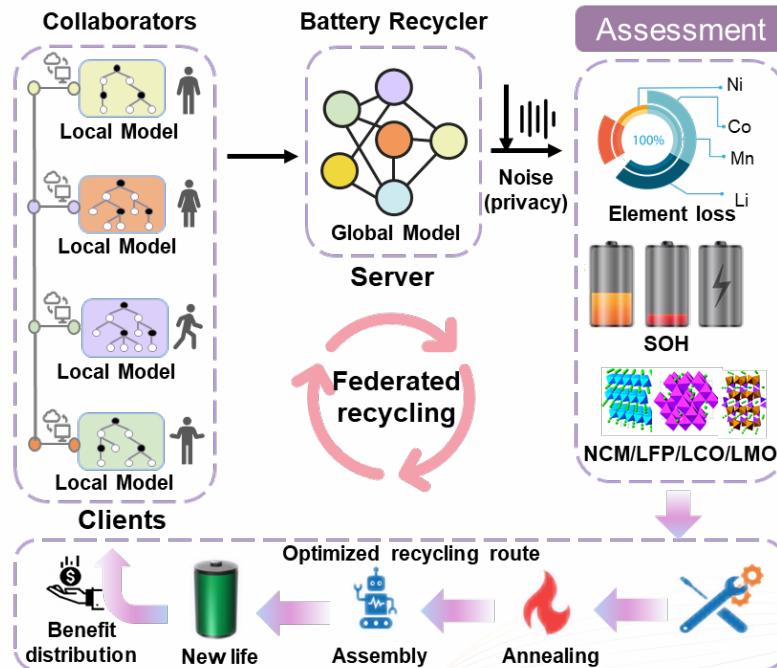


## Data characteristic

- Heterogeneous
- Small volume
- Privacy concern (formulation leakage)



Retired batteries



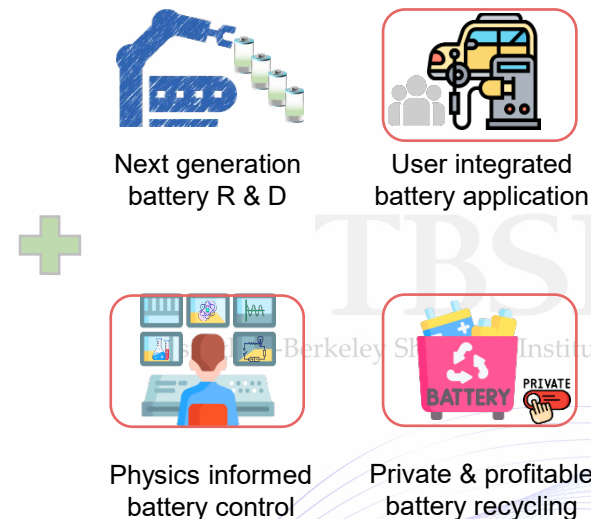
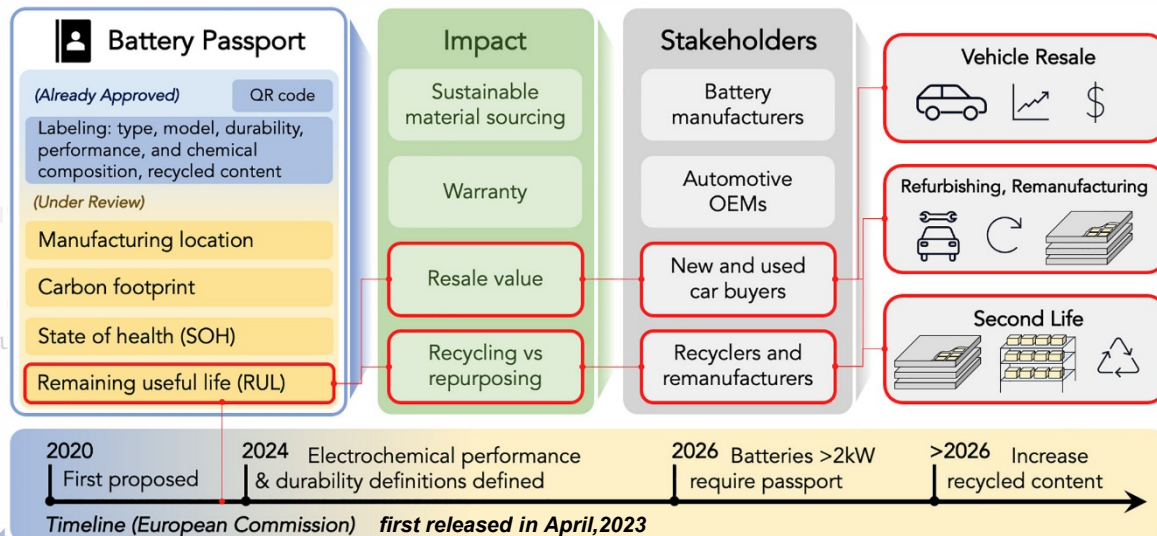
Collaborative and privacy-preserving battery recycling

## Sustainable and profitable



Let's check our repaired battery!

## The digital battery passport renews future battery ecology:



Historical information and health conditions

Different data (application) characteristics

Battery passport in European Commission,  
a 'back-looking' way (where to go)

A 'forward-looking' way, as an application-  
specific complement (how to do)





The digital battery passport enables machine learning driven battery lifecycle management and optimization by:

- accelerating battery R&D by efficiently searching for promising material candidates;
- ensuring safe and incentivized primary life applications by building user portrait;
- maximizing residual values in secondary life by leveraging historical usage patterns;
- empowering collaborative, privacy-preserving and profitable battery recycling.

Therefore, the digital battery passport is a valued asset, leading us to a sustainable and smart living in the future.

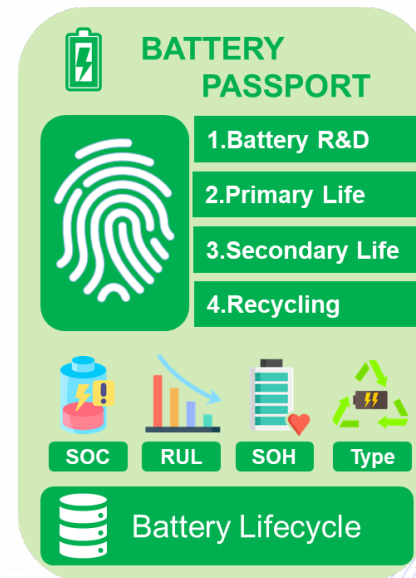
## WE ARE SAD TO SHARE THE NEWS OF THE PASSING OF JOHN B. GOODENOUGH



Credit: The University of Texas at Austin

Goodenough, the co-inventor of lithium-ion battery,  
the Nobel Laureate Winner, 2019

Story continues...



Lithium-ion battery is still young  
and will be forever with us



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## Thanks! Q&A