

# Repurposing of Lithium-ion Batteries

Launch of a Whitepaper on Technology and Market Insights



SINGAPORE  
BATTERY  
CONSORTIUM

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*Catalyzing Battery Collaborations in Singapore and Beyond*

**Dr. CHIAM Sing Yang**  
Director, Singapore Battery Consortium





SINGAPORE  
BATTERY  
CONSORTIUM

**THE LOCAL AND REGIONAL PLATFORM  
FACILITATING INTERACTIONS AMONGST  
PUBLIC AND PRIVATE PERFORMERS**



## Our Mission

To foster strategic R&D partnerships amongst public research performers and industry players in the development and advancement of battery technologies. We aim to develop and catalyze the local ecosystem in battery related technologies through this platform.

## Our Vision

To be the leading regional platform impacting the growth and translation of advanced battery related technologies through innovation driven partnerships. We aim to make Singapore the authoritative voice in battery related technologies and a place for private companies, public stakeholders and researchers to come for innovation

### Battery Pack & Modules

- *End-users, product players*
- *Pack suppliers*
- *Cooling, BMS solutions*
- *Design, materials solutions*
- *Test bedding*

### Battery Materials & Cells

- *Cells manufacturer*
- *Materials supplier*
- *Pilot cell production and testing*

### Battery Reuse & Recycling

- *Recycling industry*
- *Raw material companies*
- *Support in process development*
- *Scale up testing*

### Steering Committee



NATIONAL RESEARCH FOUNDATION  
PRIME MINISTER'S OFFICE  
SINGAPORE



### Observer



Smart Energy, Sustainable Future

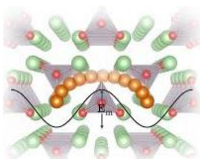
### Strategic Partners





# Current Consortium Members

## Materials



## Cells



## Modules & Packs



## Recycling



## Testing Certification Standards

**volt14**  
Batteries Redefined

**ARKEMA**  
INNOVATIVE CHEMISTRY

**UNIGRID BATTERY**

**LEI** ROVILUS  
Energize Perfection

**GenPlus**  
POWERING A SUSTAINABLE FUTURE

**greenU-ION**

**UL**

## 29 Industry Members

**NIPPON CHEMICAL INDUSTRIAL**

**CRODA**  
Innovation you can build on™

**GREEN ENERGY INVESTMENT HOLDING**  
GREEN WASTE RECYCLING COMPANY

**2Dto3D**

**Regentech**

**muRata**  
INNOVATOR IN ELECTRONICS

**dp**  
durapower

**LiRON**

**ATL**

## Product Players/End Users

**ROLLS ROYCE**

**SPgroup**

**ION MOBILITY**

**HUAWEI**

## Solution Providers

**SIEMENS**  
Ingenuity for life

**HIOKI**

**BEYOND LIMITS**

## Activities & Events



- Market & Technology intelligence
- Project scoping
- Stakeholders engagement
- Seminars, workshops, roundtables, exhibition, conferences

## More than 50 IHL Members



**Prof. Jackie YING**  
Nanyang Technological University

- 3D printed functional electrodes/batteries
- Advanced analytical techniques for battery performance
- Operando techniques for mechanism/battery analysis



**Dr. Wang Yifan**  
REPUBLIC POLYTECHNIC

- All solid state thin film lithium ion battery
- Nanostructured and porous materials for energy storage
- Additives for battery slurry



**Dr. Wang Yidong**  
NANYANG

- Multifunctional carbon materials for energy storage
- Fast charging LiFePO<sub>4</sub>
- Hybrid nanomaterials for energy storage



**Prof. Tseng King Jet**  
SINGAPORE POLYTECHNIC

- Battery state of charge and capacity estimation
- Battery management system
- Applications of energy storage systems



**Dr. Stephen Wong**  
SINGAPORE POLYTECHNIC

- Lightweight battery casing design & fabrication (aluminum, magnesium, metal composite)
- Integration of mechanical, electrical & thermal features in battery packaging
- Thermal management for battery health monitoring



**Dr. Li Xiaodong**  
SINGAPORE POLYTECHNIC

- Recycling of spent lithium ion batteries
- Low cost, fast disassembly processes
- Green, cost-effective, and environmentally friendly processes



**Dr. Valerio ISONI**  
Institute of Chemical Engineering Research

- Chemical process development: from lab scale to pilot plant
- Sustainable alternative chemical processes of the future
- Continuous chemical processing



**Prof. Palani Balaya**  
NUS

- Non-flammable sodium-ion battery for stationary applications
- Ultra safe lithium-ion battery for EV applications
- Environmental friendly organic electrodes for solid state battery technology



**Dr. Liu Zhaojin**  
Institute of Materials Research and Engineering

- Lithium-ion batteries (electrode materials, packaging)
- Solid state batteries (electrolyte materials, packaging)



**Dr. Zhang Yugen**  
Institute of Materials Research and Engineering

- Organic carbon materials for energy storage
- Organic/inorganic composites for battery applications



**Dr. Jason PNG**  
Institute of Materials Research and Engineering

- Compatible wireless charging to batteries
- Smart wireless charging management with BMS
- Optimal electrical and thermal performance management



**Dr. Yan Fan**  
Institute of Materials Research and Engineering

- Sensor calibration & measurement, sensing data correlation & acquisition
- Battery temperature monitoring technology
- Machine learning & artificial intelligence data analysis for battery thermal management systems



**Prof. Madhavi Srinivasan**  
NANYANG TECHNOLOGICAL UNIVERSITY

- Advanced lithium, sodium, multivalent zinc, aluminum and fluoride ion batteries
- Flexible structural batteries
- Supercapacitors, hybrid Li/Pb capacitors
- Lithium ion batteries e-waste recycling



**Dr. Yan Shanshan**  
Institute of Materials Research and Engineering

- Product remanufacturing technologies and know-how
- AI assisted predictive analysis and digital twin
- Life cycle cost and environmental impact analysis



**Dr. Suresh K. Palanisamy**  
Ngee Ann Polytechnic

- Electrodes/recipients for lithium ion batteries
- Electro active materials
- Material recovery



A Whitepaper Launch on:

## Repurposing of Lithium-ion Batteries Technology and Market Insights

### Content Outline

- I. Background Introduction
- II. Global Trend and Market Overview for Second Life Batteries
- III. Value Chain and Key Players in Second Life Battery Market
- IV. Key Challenges and Technology Gap in Battery Repurposing
  - Challenges in Battery Repurposing
  - Cost of Battery Repurposing
  - Standards for Battery Repurposing
- V. Innovation Landscape and Technology Review
  - Patent Landscape for Battery Diagnostic, Grading, Sorting and Rejuvenation
  - Patent Landscape for Battery Disassembly
  - Emerging Technologies for Battery Diagnostic, Grading and Sorting
  - Emerging Technologies for Battery Rejuvenation and Regeneration
  - Emerging Technologies for Battery Disassembly and Automation
- VI. Opportunity for Singapore in Battery Repurposing
  - Overview of Singapore Ecosystem
  - Case Examples for Second Life Battery Implementation
  - Future Outlook



Contact us for any queries and access to the whitepaper  
[contact@batteryconsortium.sg](mailto:contact@batteryconsortium.sg)  
[www.batteryconsortium.sg](http://www.batteryconsortium.sg)



# SBC & The Singapore Ecosystem

**GenPlus<sup>®</sup>**  
POWERING A SUSTAINABLE FUTURE

**ROVILUS**  
Energize Perfection

**ARKEMA**  
INNOVATIVE CHEMISTRY



SINGAPORE  
BATTERY  
CONSORTIUM

**SUTD**  
SINGAPORE UNIVERSITY OF  
TECHNOLOGY AND DESIGN



**Temasek**  
POLYTECHNIC



**durapower**

**a** Agency for  
Science, Technology  
and Research  
SINGAPORE



**SYH**  
SECURE DATA DESTRUCTION  
ELECTRONIC WASTE RECYCLING

**VDE**  
RENEWABLES

**SIEMENS**  
Ingenuity for life

**BEYOND LIMITS**

**SPgroup**

**HIOKI**





**durapower**



**E-Mobility  
Platforms**



**Specialty  
Platforms**



**Stationary  
Applications**



## Deployment of 2<sup>nd</sup> life batteries for ESS by DP

- >10MWh 2<sup>nd</sup> life ESS deployed
- Use cases includes EV charging, Peak shaving, Microgrids



## GenPlus<sup>®</sup>

POWERING A SUSTAINABLE FUTURE

Evaluates and deploys  
retired EV batteries for  
2<sup>nd</sup> life application



**Large local configurable capacity @SG for growth**

- Processing capability of up to 60MWh/year in Phase 1
- Potential to grow to 200MWh/year with current facility



**Factory process based on UL 1974**

- Visual and physical inspection
- Remaining usable capacity and cycle life
- Self discharge evaluation
- BMS evaluation

**Focus on sustainable and responsible processes**



- Regenerative chargers to minimize energy use in battery testing



- Waste sorted, recycled where possible
- Proper and responsible disposal process



## MOU signed in 2020

Underwriters Laboratories and Singapore Battery Consortium Sign Agreement to Collaborate on Battery Technology

<https://ul.org/SBC>

## Areas of Partnership

- Battery standards awareness and education
- Outreach for battery safety science
- Build global partnerships

## **UL 1974** Standard for Evaluation for Repurposing Batteries

- National standard for both the US and Canada.
- Joint webinar sessions, consultations with experts

Look out for upcoming Masterclass series in **Jan 2021** Batteries Safety & Standards



Engaging sessions on battery safety science and standards



## Chemistry to System Design of Lithium-Ion Batteries

**19<sup>th</sup> Nov ,11am**

Comprehensive & fast design of multi physics simulation for new and 2<sup>nd</sup> life batteries



**SBC – VDE Webinar July 2020**  
Battery Handling / Safety / Transport

Look out for upcoming Battery Training Workshop (**Dec 2020**), covering battery handling, safety, transport, including special training session by Hioki



## Upcoming Research Plans

- Battery Analytics for New and 2<sup>nd</sup> Life Batteries
- Advancing Refurbishment and Direct Recycling Methods.





## Singapore startup claims breakthrough in Lithium-ion battery recycling

Singapore-based Green Li-ion says its tech can ease the looming e-waste crisis by dramatically increasing the efficiency and profitability of rechargeable battery recycling.

**PRODUCES 99.9%  
PURE BATTERY  
CATHODE**

### Purer

- High purity recovery
- LFP processing
- Recovery of Li and Co

### Greener Chemistry

- Zero Toxic Discharge
- Efficient co-precipitation
- Reusable solutions

### Faster

- Faster than current pyro and hydro
- Process all batteries
- No sorting required



**SYH**  
SECURE DATA DESTRUCTION  
ELECTRONIC WASTE RECYCLING

## Lithium Battery Recycling

- Proprietary technology to recycle lithium-ion batteries, recovering metals such as cobalt, copper and lithium.
- Approved Lithium ion battery recycler by NEA since December 2017.

## Smelting (Pyro-metallurgy) Facility in Singapore

- New modern, highly-advanced smelting facility in Singapore to extract and recover metals and materials from waste materials and metal scraps.
- Aggregate processing capacity of ~1,000 tons per month with the capability of processing waste battery powders.



Singapore facility  
capable of recycling 14  
tonnes per day



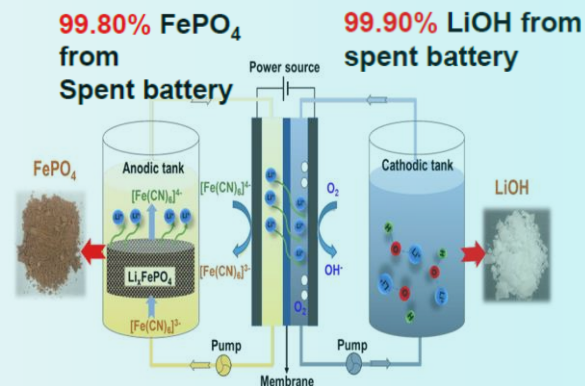


## Advanced redox process for extraction of $\text{FePO}_4$ and Li

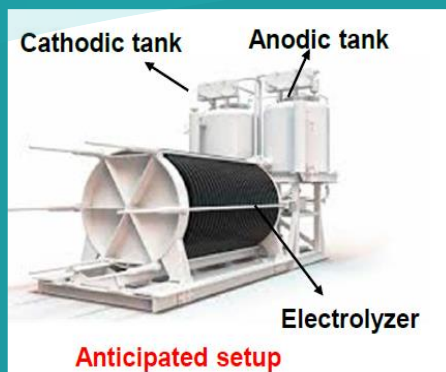


### NUS-Temasek Polytechnic

- Hydrometallurgy and electrochemical method
- Use of ferricyanide-based leaching solution to recover  $\text{FePO}_4$  and  $\text{LiOH}$  (99.9% purity) from spent LFP battery



- Cost effective
- Low chemical usage
- Continuous process
- No secondary pollution



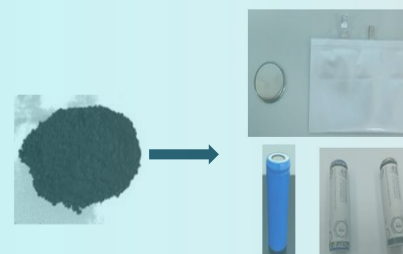
Singapore – CEA Alliance for Research in Circular Economy (SCARCE) @NTU



NANYANG  
TECHNOLOGICAL  
UNIVERSITY  
SINGAPORE



### Recycling of lithium-ion batteries



Refabricated new batteries

- Recover materials from spent LIBs and convert them into useful second life electrode materials
- Develop efficient mechanical separation methods
- Work on environment-friendly hydrometallurgical processes

ScienceDaily

Your source for the latest research news

Date: August 26, 2020

Scientists use fruit peel to turn old batteries into new

- Hydrometallurgy
- Replacing acid precipitating extraction with fruit waste
- Organic acid in citrus fruit waste



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### FOCUS AREA



Battery Materials



Battery Cells  
Production



Battery Reuse  
and Recycling



Battery Packs  
and Modules

### Steering Committee



NATIONAL RESEARCH FOUNDATION  
PRIME MINISTER'S OFFICE  
SINGAPORE



Enterprise  
Singapore



Observer



Strategic Partners



## SNAP SHOT OF THE CONSORTIUM

### 29 Industry Members

- Battery materials/cells
- Battery modules/packs
- Battery Reuse/Recycling



### 56 Scientist/Academics

- 4 Universities, 5 Polytechnics
- 10 Research Institutes
- >3000 papers, >90 IPs



### Multiple Activities

- Market intelligence, project scoping, stakeholders engagement
- Tech road mapping, whitepapers
- Seminars, workshops, roundtables, exhibition, conferences

