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Managing Change in RD&D

Case studies in program management

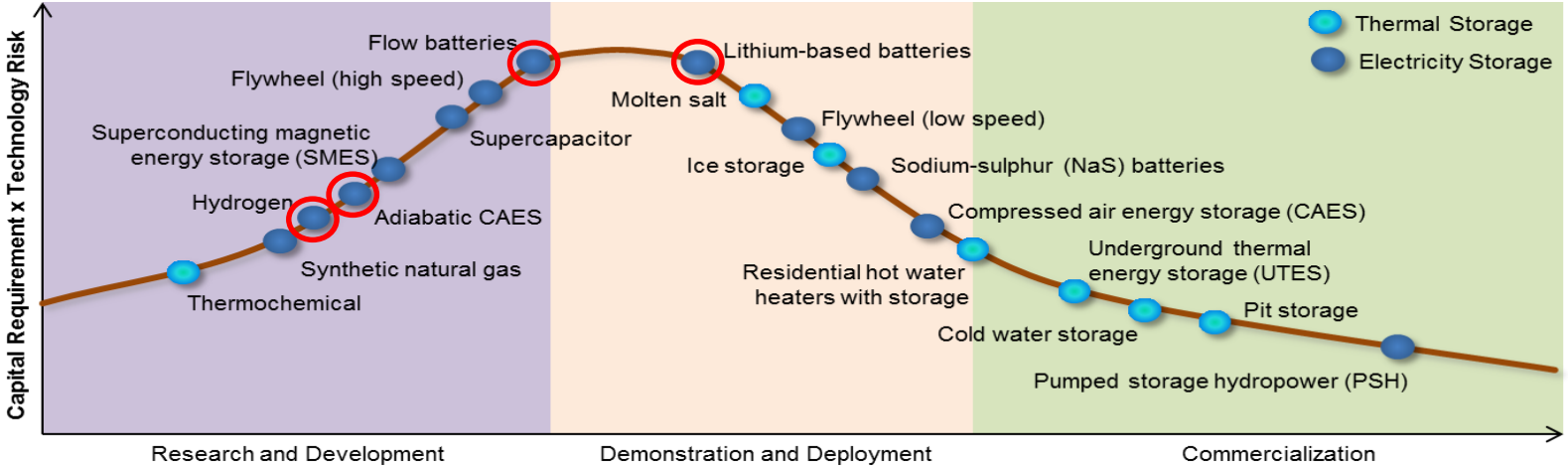
Energy Storage for Grid Security and Modernization

National Research Council of Canada

About NRC

- Canadian Federal Research and Technology Organization
- Operate >40 research programs, with an annual budget of **~$750M**
- Over **4,000** employees across **16** sites
- World-class technical expertise and facilities

Technical Change will continue to exist



Technology:

- Li-ion have become the most installed new battery type (2012-2016)
- Cell costs have been decreasing and are expected to continue:
  - Flow batteries ($680 → $350/kWh)
  - Li-ion ($550 → $200/kWh)
- Fully Installed costs are higher:
  - Inverter and interconnect ~$450/kW
  - BMS and control ~$325/kW
  - Installation and contingency ~$250/kW

Research and Development:

- University based research Networks
  - Future Energy Systems Research Institute (U of Alberta)
  - NSERC NEST Network (Ryerson)
  - UBC/Fraunhofer Clean Energy Partnership
- US DOE Energy Storage Program
- Energy Storage Integration Council (ESIC)

Within global marketplaces…..

China's Dominance is Driving Global Investment

Chinese control of critical mineral processing and battery manufacturing has spurred investments in alternative value chains

Europe Chases China with 5B Euro Battery Plan

The EU battery market could represent a $250B Euro opportunity. The EU has developed a plan with industry to incentivize battery manufacturing on the continent

Australia is Investing AU$135 million in Research

Australia's Future Battery Industry Collaborative Research Centre brings together governments and industry. The state of Western Australia has also developed a Future Battery Industry Strategy

Japan is Investing in Lithium-ion Research

Japan has invested US$90 million to establish a Lithium-ion Battery Technology and Evaluation Center (LIBTEC)

The US has Established a Battery Innovation Hub

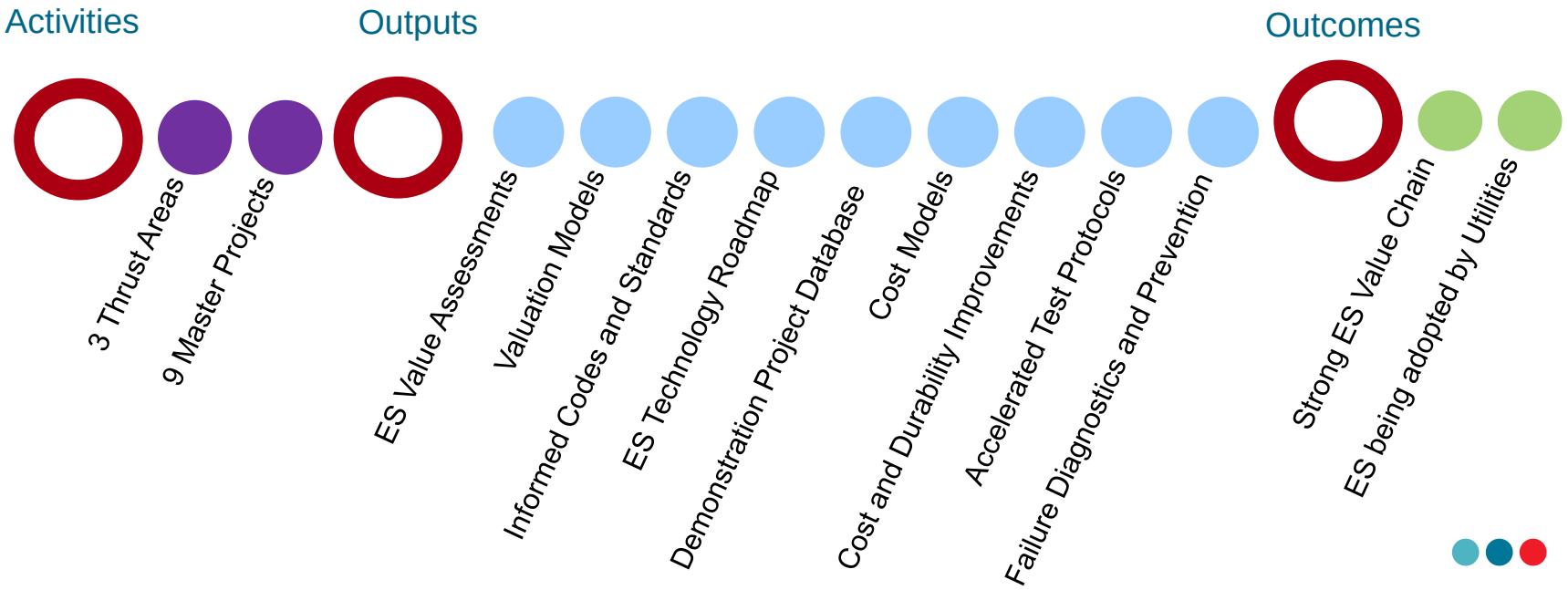
The US Department of Energy has invested US$120 million in a Joint Center for Energy Storage Research

India to Invest US$3.5 Billion in EV Value Chain

India has allocated US$3.5 billion to build EVs, install charging infrastructure, and manufacture lithium-ion batteries

Energy Storage for Grid Security and Modernization Program

To demonstrate at TRL7, an installed **cost reduction** from the current ~$1000/kWh to under $500/kWh and from the current ~$2500/kW to less than $1250/kW, while increasing the **operating lifetime** to >15 years from today's 5-7 years and **strengthening** the Canadian Energy Storage supply chain.



Based around a global value chain

*To demonstrate at TRL7 an installed **cost reduction** from the current ~$1000/kWh to under $500/kWh and from the current ~$2500/kW to less than $1250/kW, while increasing the **operating lifetime** to >15 years from today's 5-7 years and strengthening the Canadian Energy Storage supply chain.*

Materials	Components	Controls	Integrators	End Users
• *Resource extraction* • *Materials processing*	• *Batteries (flow, li-ion, lead acid, metal-air)* • *CAES* • *H2 storage*	• *Smart-grid interfaces* • *Inverter* • *Control system*	• *Engineering firms* • *System integrators* • *Installers*	• *Utilities* • *Independent power producers* • *Micro-grids*

ENABLERS: capital, business / technology experts, incubators, regulators, government

Program Planning

Strategic Support and Analysis

- Techno-Economic Assessments
- Technical Support of Codes & Standards

Activity #	Activity/Objective
1.1.1	Establish **common methodology for TEA of ES** systems in Canada, and ensure compatibility with North American and International export markets
1.1.2	
1.1.3	

Milestone #	Responsibility	Due Date	Milestone Category	Milestone
MPO 1.1.1.1	Kourosh Malek	March-31-16	Capability	TEA capacity increased by 50% (total 3 FTE) within already built TEA competency team
MPO 1.1.1.2	Kourosh Malek	March-31-18	Business	A complete partnership agreement is established for maintaining and distribution of Canadian content of the valuation tools, ensuring external awareness on NRC unique capability for TEA
MPO 1.1.1.3	Kourosh Malek	March-31-16	Technical	Standard valuation tool and 1st-gen analysis model is chosen and deployed to ES stakeholders and Canadian users

Client Dr
R&D

- Accelerated Testing

Defer
structure
stment

Canadian Energy Storage Roadmap

"This project initiates for the first time, a holistic approach to develop and maintain a multi-year (2016-2021) electricity storage (ES) roadmap for Canada. It aims to understand market potential, roadblocks and actions required at the planning, procurement, rate treatment, interconnection, market, and regulations steps for adopting ES technologies in Canada by 2021. "

1. Market Opportunity

Identify ES Use Cases

- Define specific application requirements
- Identify the impacts on grid power planning and operations
- Review the current market structure

2. Technology Assessment

Assess ES Technologies and Trends

- Match technology and application requirements
- Review early ES experience and comparable jurisdictions
- Propose evaluation and performance frameworks

3. Economic Development

Identify Technology Opportunities

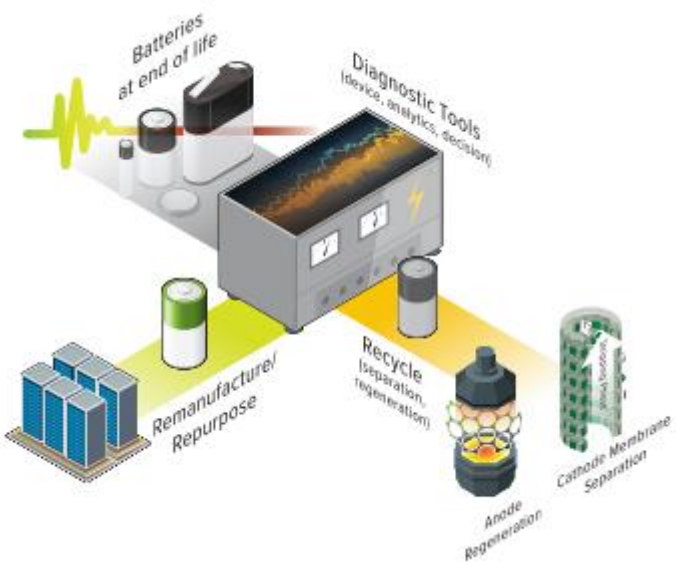
- Analyze province, industries, strengths and economic impact
- Assess environmental and GHG impacts
- Recommendations and next steps

End-of-Life Lithium-ion Battery Options

Timeline: June 2019 to March 2022

Scope: The main objective of this project is to evaluate and develop protocols, tools, and technologies to remanufacture, repurpose, and recycle lithium-ion batteries (LiB), which currently are largely disposed of in landfills.

- Task 1: Investigate/develop a testing standard to evaluate battery conditions and diagnostic tools that determine residual battery life and defectiveness for further safe use
- Task 2: Develop separation methods for polymer component, copper and aluminum current collectors, and positive/negative electrodes inspired by mining industry practices and technologies
- Task 3: Perform life cycle and techno-economic analyses to direct and evaluate the impact of the project.

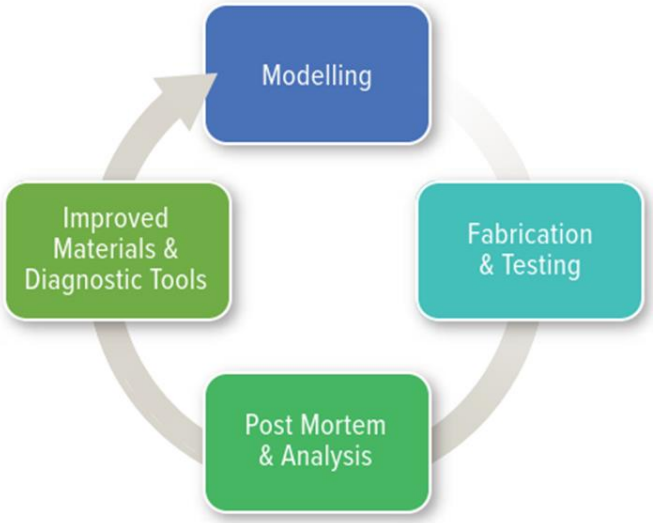


Degradation Mechanisms of Nickel-rich NMC Lithium-ion Batteries

Timeline: November 2019 to March 2020

Scope: The ability to identify the root cause of capacity fading, and diagnose/predict the SOH of a Lithium-ion battery is an important and challenging goal. The objective of this project is to investigate the structure change-impedance response (low frequency diffusion region) relationship under high voltage, high temperature, and prolonged cycling operation conditions using NMC811 coin cells as samples. It is expected that the knowledge and methodology from this project will provide a diagnosis tool for early degradation prediction for Lithium-ion batteries. The scope of work will include:

- Benchmarking
- Proof of Concept of decouple diffusion from Warburg impedance
- Post chemical-physical characterizations of tested cells
- Modeling analysis on EIS data and parameter estimation / extraction.



Assessing Program Performance

Master Project Plan

- Technical Support of Demo Projects
- Component Validation

Project Activities

- PERD F22.008 - Electrochemical Energy Storage for the Integration of Renewables
- DND Power Sources for the Canadian Forces

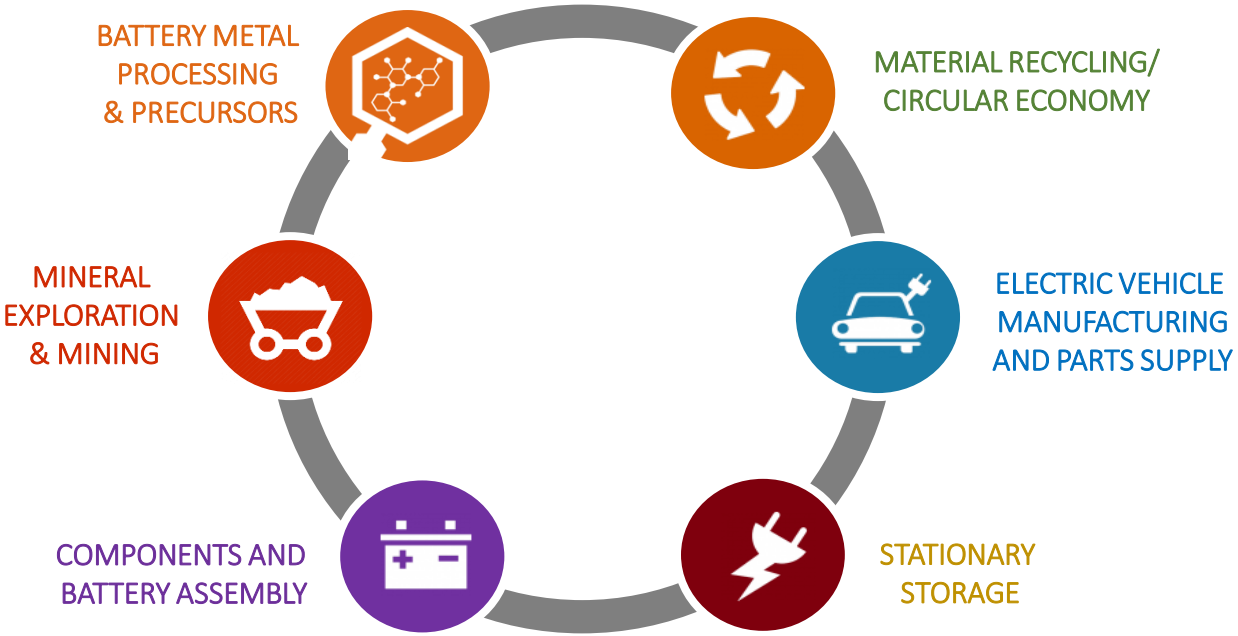
Immediate Output

- Database of demonstration projects with key performance and reliability statistics
- Provision of Facilities & Technical Services to the Canadian ES Value Chain
- TRM
- Codes & Standards Support

Outcome

- A reduction of the site specific engineering costs due to standardization & Integration
- Cost reduction at TRL7+ of <$1500/kW & $750/kWh with >10 yr durability

What's Next?


BATTERY METAL PROCESSING & PRECURSORS
MATERIAL RECYCLING/ CIRCULAR ECONOMY
ELECTRIC VEHICLE MANUFACTURING AND PARTS SUPPLY
STATIONARY STORAGE
COMPONENTS AND BATTERY ASSEMBLY
MINERAL EXPLORATION & MINING

Thank you

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Program Scope

Strategic Support and Analysis

- Techno-Economic Assessments
- Technical Support of Codes & Standards
- Technology Roadmaps

Demonstration and Validation

- Technical Support of Demo Projects
- System Integration
- Component Validation

Client Driven R&D

- Manufacturability
- Material Improvement
- Accelerated Testing

✓**Cost**

✓**Durability**

✓**Market Acceptance**

Defer infrastructure investment

Peak shaving and arbitrage

Integrate renewables

Thrust 1 – Strategic Support and Analysis

MP1.1 Techno-Economic Assessments

- Establish common methodology for TEA of ES systems in Canada, and ensure compatibility with North American and international export markets
- Develop / adapt tool to collect, enrich, and maintain market information for emerging ES technologies
- Apply and demonstrate uniform ES use case analysis and performance matrices across all Canadian jurisdictions

MP1.2 Technical Support of Codes and Standards

- Harmonize C&S across North America, filling critical gaps in cost / time for project installation
- Use C&S to reduce costs of ES Systems (repeatability)
- Provide C&S consulting to ES stakeholders (witness testing, C&S feasibility)

MP1.3 ES Technology Roadmap

- Assess and maintain the SOTA in ES technologies, identifying technical drivers behind performance, cost, and durability trends in individual technologies and BOP, including the economic impact to Canada
- Analyze the ES market (supply mix, regulations, market operation, policy drivers and stakeholders) in each Canadian jurisdiction over time, in order to obtain a clear path forward for the integration of ES in the marketplace.

Thrust 2 – Demonstration and Validation

MP2.1 Demonstration and Validation

- Provide operational guidelines (design of experiments / testing protocols) for key ES technologies and applications at different phases of operation in order to ensure a common framework for the evaluation of ES projects
- Collect and maintain validated 3rd party data from ES projects based on agreed upon variables and frequency in order to validate design and performance to both technology providers and end-users
- Analyze operational data, identifying technical risks and benefits in order to provide the value chain with options for suppliers, technologies, systems and components

MP2.2 System Integration

- Development of system cost models in order to identify areas for component cost reduction, and future system costs
- Adoption of standardized communication and data management solutions in order to realize stacked benefits, reduce system costs, and ensure greater value chain participation
- Ensure adoption of improved energy storage system models in power system planning tools in order to provide system operators and planners with detailed ES operational predictions

MP2.3 Component Level Validation

- Establish standardized testing and validation platforms / protocols for LiB single cells and packs on performance, efficiency, aging, decay and safety to reduce component and system integration problems
- Develop standardized testing tools, procedures / protocols for key BOS components (power electronics components including inverter / converter, DMS, BMS, TBMS, controls, communications) to reduce component cost and system integration issues
- Establish test tools and procedures and conduct tests on components related to CAES to reduce component cost, increase system efficiency and reduce system integration issues
- Conduct tests on hydrogen tolerance levels of P2G components to increase the P2G technology readiness level

Thrust 3 – Client Driven R&D

MP3.1 Manufacturability

- Increasing the market share of Canadian vanadium suppliers in the world-wide VRB electrolyte supply chain (manufacturing process optimization and quality improvement)
- Development of low cost materials and manufacturing methods for battery grade graphite and graphene
- Improving the supply of Canadian alternative battery materials into the worldwide supply chain (Zinc, Lead, Lithium)
- Engage existing automotive / industrial manufacturing supply chains in the ES marketplace

MP3.2 Materials Improvements

- Assessment of upcoming ES technologies / materials
- Improve SOTA of ES components in performance and durability (across technologies)

MP3.3 Accelerated Testing

- Diagnose degradation and failure mechanisms of key ES components using in situ characterization techniques in order to provide guidance in material improvement
- Develop in situ testing tools, procedures and protocols and modeling for state of health, state of charge, and remaining life prediction to increase confidence in system lifetimes
- Develop accelerated testing procedures / protocols and lifetime predictive models to decrease testing and evaluation time for new materials