Managing Change in RD&D

Case studies in program management

Energy Storage for Grid Security and Modernization

National Research Council of Canada
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.

Activities | Outputs | Outcomes
--- | --- | ---
3 Thrust Areas | Valuation Models | Strong ES Value Chain
9 Master Projects | Informed Codes and Standards | ES being adopted by Utilities
ES Value Assessments | ES Technology, Roadmap | Cost and Durability Improvements
Demonstration Project Database | Cost Models | Failure Diagnostics and Prevention
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**
- Resource extraction
- Materials processing

**Components**
- Batteries (flow, li-ion, lead acid, metal-air)
- CAES
- H2 storage

**Controls**
- Smart-grid interfaces
- Inverter
- Control system

**Integrators**
- Engineering firms
- System integrators
- Installers

**End Users**
- 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
- Market Acceptance

Program Planning

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

<table>
<thead>
<tr>
<th>Milestone #</th>
<th>Responsibility</th>
<th>Due Date</th>
<th>Milestone Category</th>
<th>Milestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPO 1.1.1.1</td>
<td>Kourosh Malek</td>
<td>March-31-16</td>
<td>Capability</td>
<td>TEA capacity increased by 50% (total 3 FTE) within already built TEA competency team</td>
</tr>
<tr>
<td>MPO 1.1.1.2</td>
<td>Kourosh Malek</td>
<td>March-31-18</td>
<td>Business</td>
<td>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</td>
</tr>
<tr>
<td>MPO 1.1.1.3</td>
<td>Kourosh Malek</td>
<td>March-31-16</td>
<td>Technical</td>
<td>Standard valuation tool and 1st-gen analysis model is chosen and deployed to ES stakeholders and Canadian users</td>
</tr>
</tbody>
</table>
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**

**Project Activities**
- Technical Support of Demo Projects
- PERD F22.008 - Electrochemical Energy Storage for the Integration of Renewables
- Database of demonstration projects with key performance and reliability statistics
- TRM
- Codes & Standards Support

**Immediate Output**
- A reduction of the site specific engineering costs due to standardization & Integration
- DND Power Sources for the Canadian Forces

**Outcome**
- Component Validation
- Provision of Facilities & Technical Services to the Canadian ES Value Chain
- Cost reduction at TRL7+ of <$1500/kW & $750/kWh with >10 yr durability
What’s Next?

- Mineral Exploration & Mining
- Battery Metal Processing & Precursors
- Components and Battery Assembly
- Stationary Storage
- Electric Vehicle Manufacturing and Parts Supply
- Material Recycling/Circular Economy
Thank you

Adam Tuck
Program Leader, Energy Storage for Grid Security and Modernization
Tel: 604-221-3058
Adam.tuck@nrc-cnrc.gc.ca

Website: www.nrc-cnrc.gc.ca/energystorage
www.nrc-cnrc.gc.ca/stockagedenergie
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