

# Long-Duration Energy Storage and Redox Flow Batteries

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*Lockheed Martin Australia Response to the Australian Federal Government's Technology Investment Roadmap*

June 21, 2020

**LOCKHEED MARTIN**  
Australia



Lockheed Martin Australia welcomes the release of the Australian Government's Technology Investment Roadmap discussion paper and supports the paper's stance on the critical role of renewable energy and energy storage in improving energy reliability, security and affordability, while reducing emissions and promoting employment and growth opportunities. As an Australian industry leader, we are pleased to provide the following feedback in-line with the discussions paper's core five stakeholder questions.

## A. INTRODUCTION: CHALLENGES, GLOBAL TRENDS AND COMPETITIVE ADVANTAGES TO CONSIDER

As Australia continues to advance clean, reliable, secure and affordable energy, the grid will undergo unprecedented change as intermittent, non-dispatchable renewables continue to expand and displace traditional power generation sources. This transformation is well on its way.

Parts of the National Energy Market have among the world's highest levels of wind and solar, and forecasts – with the Australian Energy Market Operator (AEMO) – significant growth during the next 20 years. But while these changes will help Australia achieve renewable and climate change goals, they also present a new **challenge**.

Installing higher amounts of renewables over the next five to ten years without sound, co-ordinated planning, risks damaging grid stability as well as technical and economic efficiency. Australia's large landmass also creates challenges for the reliable transmission and distribution of electricity over large distances from centralised generators.

To address these challenges, the grid will require energy storage with a range of durations – including short-, medium- and long-duration – that is deployable in geographically diverse locations. AEMO's Integrated System Planning Insights paper, August-2019, lists the first insight as "The NEM needs a portfolio of varying energy storage durations..." listing opportunities for six- to 12-hour storage solutions.

Energy storage technologies such as Lithium-ion have served markets requiring short- to medium-discharge durations of four hours or less. However, the **global trend** toward mass renewable generation reveals the need for a new class of storage technologies capable of daily

long-durations of over four hours, deep discharge duty cycles and rapid, frequent response to balance supply and demand. For example, four-hour storage cannot absorb eight hours of daily solar output without a discharge and recharge cycle. Frequent cycling accelerates degradation for some battery technologies, such as Lithium-ion, requiring augmentation and increasing Total Cost of Ownership (TCO).

Beyond bulk absorption of renewable generation, longer durations provide grid operators with more flexibility throughout the day. By virtue of its greater energy capacity, a single long-duration battery can provide multiple products throughout an operating day without needing to recharge after discharge.

Finally, large-scale renewables deployment can cause significant fluctuations on the grid. These needs are best met by battery technologies that can switch between charge and discharge rapidly.

Batteries are increasingly being considered as Non-Wires Alternatives to traditional capital-intensive Transmission & Distribution projects. In addition to their upfront expense and the risk of extensive scope, schedule and budget overruns, wires projects can face significant siting and permitting challenges. Batteries can be strategically sited to meet local demand, sidestepping the need for extensive right-of-way, siting, permitting and construction processes.

In New York state, a 32 GW market<sup>1</sup>, the grid operator, regulators and utilities have enabled dual-use cases where batteries can function as Non-Wires Alternatives and provide wholesale market services. In California, a 46 GW market<sup>2</sup>, state regulators have identified the need for 1 GW of long-duration storage by 2026<sup>3</sup> and increasing levels in the years that follow. These changes represent the evolution of markets to accommodate increasing

<sup>1</sup>"2019 Load and Capacity Data Report," The New York Independent System Operator, Inc., April 2019. <https://www.nyiso.com/documents/20142/2226333/2019-Gold-Book-Final-Public.pdf/a3e8d99f-7164-2b24-e81d-b2c245f67904?t=1556215322968>

<sup>2</sup>"2018 Annual Report on Market Issues & Performance," California ISO, May 2019. <http://www.caiso.com/Documents/2018AnnualReportonMarketIssuesandPerformance.pdf>

<sup>3</sup>"2019-2020 Electric Resource Portfolios to Inform Integrated Resource Plans and Transmission Plans," California PUC Reference System Portfolio, March 26, 2020. <https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M330/K357/330357384.PDF>

renewables penetration and reflect the complete value long-duration storage brings.

Flexible long-duration energy storage technology can help balance the grid and deliver significant benefits to Australia's energy market while fitting within the medium- to long-term electricity opportunities identified in the discussion paper. One of many promising long-duration technologies is grid scale, low-cost flowbattery technology.

Australia has access to an abundant supply of renewable energy. This, coupled with falling generation costs, presents Australia with a significant competitive advantage. Priority should be placed on technologies that can leverage this competitive advantage and improve the reliability and affordability of energy supply.

## **B. PRIORITY TECHNOLOGIES FOR ACHIEVING SCALE THROUGH TECHNOLOGY INVESTMENTS**

Lockheed Martin believes the Australian federal government should prioritize investment in flexible long-duration energy storage technologies that target durations from six to 12+ hours. Long-duration energy storage, such as redox flow batteries, can enable increased levels of renewable energy generation and support a stable transition of Australia's electricity grid over the medium- to long-term.

The Technology Investment Roadmap discussion paper recognizes the significant government investment-to-date in driving down the costs of storage technologies such as large-scale batteries and pumped hydro, which will realise benefits beyond 2030. The investments-to-date have focused on two different technologies, Lithium-Ion and Pumped Hydro.

- **Lithium-ion** (Li-ion) is today's most rapidly growing battery technology; however, it is challenged by significant capacity degradation in high-cycling environments, as well as safety issues. Li-ion batteries have a fixed power-to-energy ratio, so long-duration applications become expensive since batteries are effectively oversized at project outset. The combination of oversized batteries and high degradation, eventually requiring augmentation of the oversized battery, means the Li-ion value proposition breaks down for long-duration, high-cycling projects. We believe Li-ion batteries are best suited for applications of four hours or less.
- **Pumped hydro projects** are long duration, typically six to 20+ hours. Owing to the technology's sheer scale and complexity, pumped hydro stations are capital



RENDERING: 10 MWAC, 100 MWh GridStar Flow installation consisting of five 2 MWAC ESUs coupled together

intensive, particularly since durations of a few hours are simply not economical. Other limitations are the geographical requirements and the risks associated with siting, permitting and construction. Unlike Li-ion or redox flow batteries, Pumped Hydro typically cannot function as a Non-Wires Alternative in urban and suburban areas.

**Redox flow batteries** are a long-duration storage technology that can fill the gap left by the limitations of other storage technologies, like Li-ion and pumped hydro, by offering several critical advantages:

- Separation of power and energy enables the owner to tailor the battery to each project's needs
- Low marginal cost of energy capacity, enabling cost-effective durations of six to 12+ hours
- Low degradation under high cycling
- 20-year system design life

Because redox flow batteries offer unique advantages, we recommend that they become an investment priority for the Australian federal government. Currently, redox flow batteries are undergoing significant research and development. It is critical to invest in this technology now to meet the challenges faced by the evolving grid and deliver benefits in the medium- to long-term.

Lockheed Martin is commercializing a new flow battery technology – GridStar® Flow. GridStar Flow is a patented technology based on the principles of coordination chemistry, offering a new electrochemistry consisting of engineered electrolytes. The electrochemical properties of the electrolytes have been designed to optimize battery performance at a competitive TCO and offer many unique properties, including:

- Six+ hours of flexible discharge
- High cycling ability
- A system design life of 20 years
- Ability to size energy and power independently
- Ability to respond faster than traditional generation, such as gas peakers and pumped hydro, and to switch between charge and discharge modes rapidly; this empowers the customer to flexibly switch between services to maximise revenues
- Mildly alkaline, aqueous electrolytes that are safe (nonflammable, noncorrosive and stable)
- Competitive TCO

These attributes provide optionality and flexibility. GridStar Flow can switch between applications over the course of an operating day – providing, for example, frequency regulation in the early morning, smoothing ramps in late morning, bulk absorbing renewables in the afternoon, smoothing ramps in the evening and discharging in the late evening.

Each operation constitutes a value stream. The owner can optimise GridStar Flow to stack these value streams, maximizing ROI and increasing reliability. In addition, GridStar Flow's extended duration enables optimising daily operation while targeting a peak event several days in the future.

GridStar Flow can be strategically sited at constrained points, allowing it to function as a Non-Wires Alternative to capital-intensive traditional transmission and distribution projects. Since the battery is assembled on site from manufactured components, it has less scope, schedule and budget risk than traditional wires projects.

GridStar Flow is a fossil-free alternative to traditional peaking options, such as internal combustion engines or gas turbines. Unlike traditional peakers, it does not generally require air quality permits, gas pipeline access or on-site diesel fuel. In active mode, its response time compares favorably to internal combustion engines – which reach full load in under two minutes, and to gas turbines – which reach full load in under 10 minutes.

Since it can flex across applications for extended durations, it may have greater ability to stack value than traditional peaking units, which are constrained by efficiency, fuel availability and fuel prices. Fuel independence means GridStar Flow is always ready to supply peaking energy; there is no dependence on pipeline capacity or on-site fuel.

Finally, the optionality and flexibility built into GridStar Flow's design enable its applications to evolve with the grid's needs – reducing the potential for stranded costs. Combined, these attributes make GridStar Flow a compelling alternative at a competitive TCO.

By placing a priority on long-duration technologies, such as GridStar Flow, the Australian federal government will fill an important gap left by existing storage technologies and address the challenges of integrating large amounts of renewables across geographically diverse regions in Australia.

### **C. WORKING TOWARDS PRIVATE INVESTMENT**

Lockheed Martin acknowledges the important role played by government programs in promoting uptake of emerging technologies, with multiple successful projects supported by ARENA, the Clean Energy Finance Corporation or both. In several cases, these projects have also worked closely with the region's state government departments and are viewed worldwide as successful examples of energy innovation.

Focused programs such as ARENA's Advancing Renewables Program provide the Australian government with an ongoing opportunity to focus on projects which increase the value delivered by renewable energy, such as providing dispatchable renewable energy, improving grid reliability and reducing costs to end users; whilst proving the technology and commercial readiness of emerging technologies, such as long-duration energy storage.

Ongoing government support of these programs, in targeted areas such as energy reliability, will continue to accelerate the Australian uptake of new enabling technologies. This will help build local skills and jobs, leading to further investment by the private sector as technology matures, costs reduce and the market demands for storage continue to increase.

### **D. ACHIEVING SCALE - INFRASTRUCTURE, SKILLS, REGULATION AND PLANNING**

Careful consideration should be placed on technology scalability in addition to planning for skills development, infrastructure build and policy or regulatory requirements when selecting priority technologies.

An important element in scaling up projects is establishing strong industry ties to enable local industry to play a role, from supply of components and skills, to engineering and design services. Lockheed

Martin has a significant presence in Australia and has developed strong relationships with Australia's manufacturing sector through our extensive industry partnerships. Our substantial experience and relationships can be leveraged for planning local requirements over the medium- and long-term.

Regarding scale, GridStar Flow is specifically designed for large-scale projects, with a flexible configuration enabling hundreds of MW of power, and thousands of MWh of energy, as the technology is commercially deployed.

## **E. CONCLUSION: AUSTRALIA IS POSITIONED TO LEAD ENERGY INNOVATION**

As a world leader in low emissions and technological innovation, Australia is well positioned to further lead decarbonization and clean energy efforts. To support continued growth, Australia's technology investments should be responsive to emerging trends, along with the drivers influencing technology innovation. Priority should be given to technology which can scale inline with Australia's evolving requirements during the medium- to long-term, while building on Australia's role as a technology influencer.

Government investments, along with policy to drive investments in innovative storage technologies such as GridStar Flow, will help realize the full potential and benefits of Australia's abundant renewable energy resources whilst reducing emissions and improving energy security, reliability and affordability.

## **ABOUT LOCKHEED MARTIN AUSTRALIA**

Lockheed Martin Australia is an Australian company that is engaged in research, design, development, integration and sustainment of advanced technology systems, products and services. We are an industry leader in technology and defence, working with Australian partners to bring best practices and leading-edge concepts and technology to Australia.

Our innovative technologies have been contributing to the security of Australia and realisation of Australia's national interests for over 70 years and today we employ over 1,000 people with a presence in every mainland state and territory.

Lockheed Martin Australia invests in partnerships with Australia's research and industry communities to support our global supply chains, providing opportunities for technology transfer, innovation, local skilled jobs and sustainable business growth.

As an industry leader, Lockheed Martin Australia provides products and services that address some of the world's most critical issues. But our contribution doesn't end with a commitment to support Australia's national security, technology and economic growth. As a responsible corporate citizen, we also play an active role in helping to strengthen the quality of life in our country and the communities where we live and work. Through our Australian community partnerships we proudly support science, technology, engineering, and mathematics (STEM) education.

In regard to Energy solutions, globally Lockheed Martin has developed and implemented energy solutions since 1933. Recently, we've focused on innovating energy storage to address the new, disruptive challenges faced by the grid. For more details refer to:

[www.lockheedmartin.com/gridstarflow](http://www.lockheedmartin.com/gridstarflow)

[www.lockheedmartin.com/en-au/index.html](http://www.lockheedmartin.com/en-au/index.html)