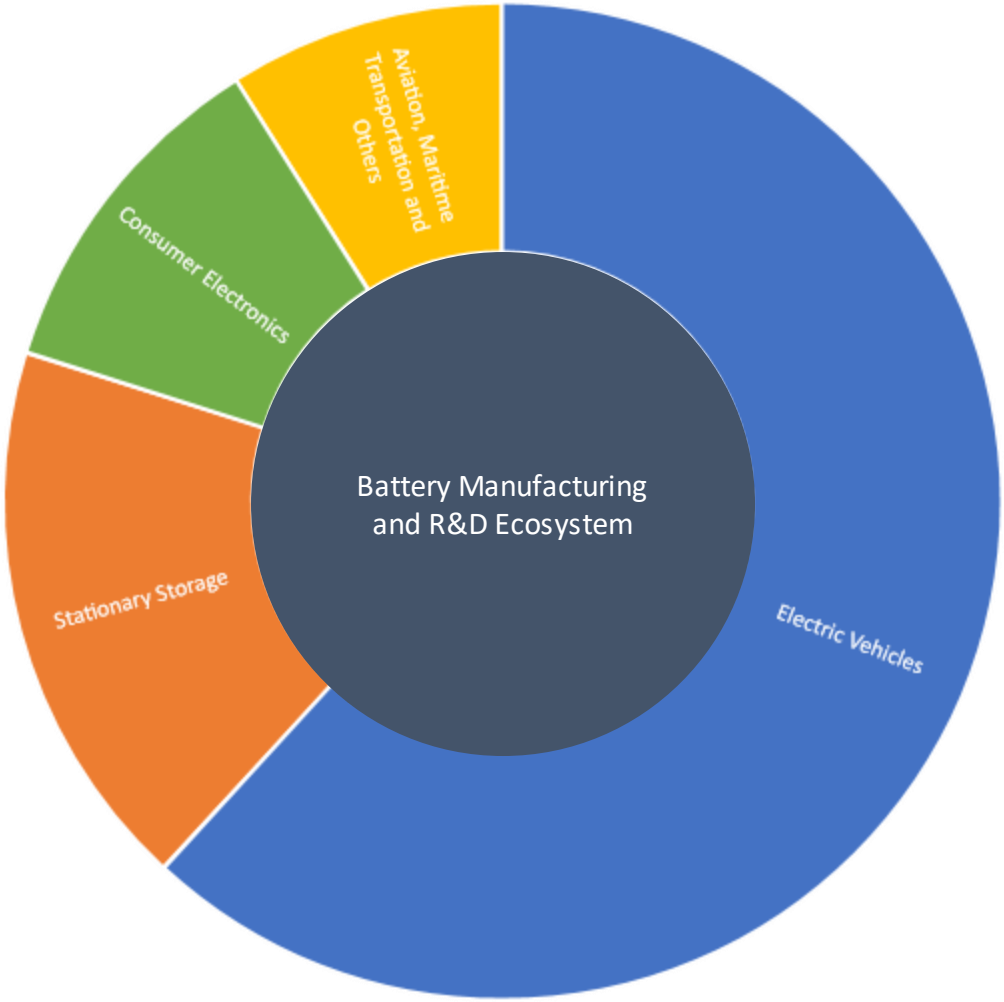
Breakthrough Battery Technologies

ROCKY MOUNTAIN INSTITUTE

Aman Chitkara | April 10, 2019 | NRRI

Transforming global energy use to create a clean, prosperous, and secure low-carbon future.

Batteries will have a key role in energy systems transformation and a multiplier effect on key sectors of the economy



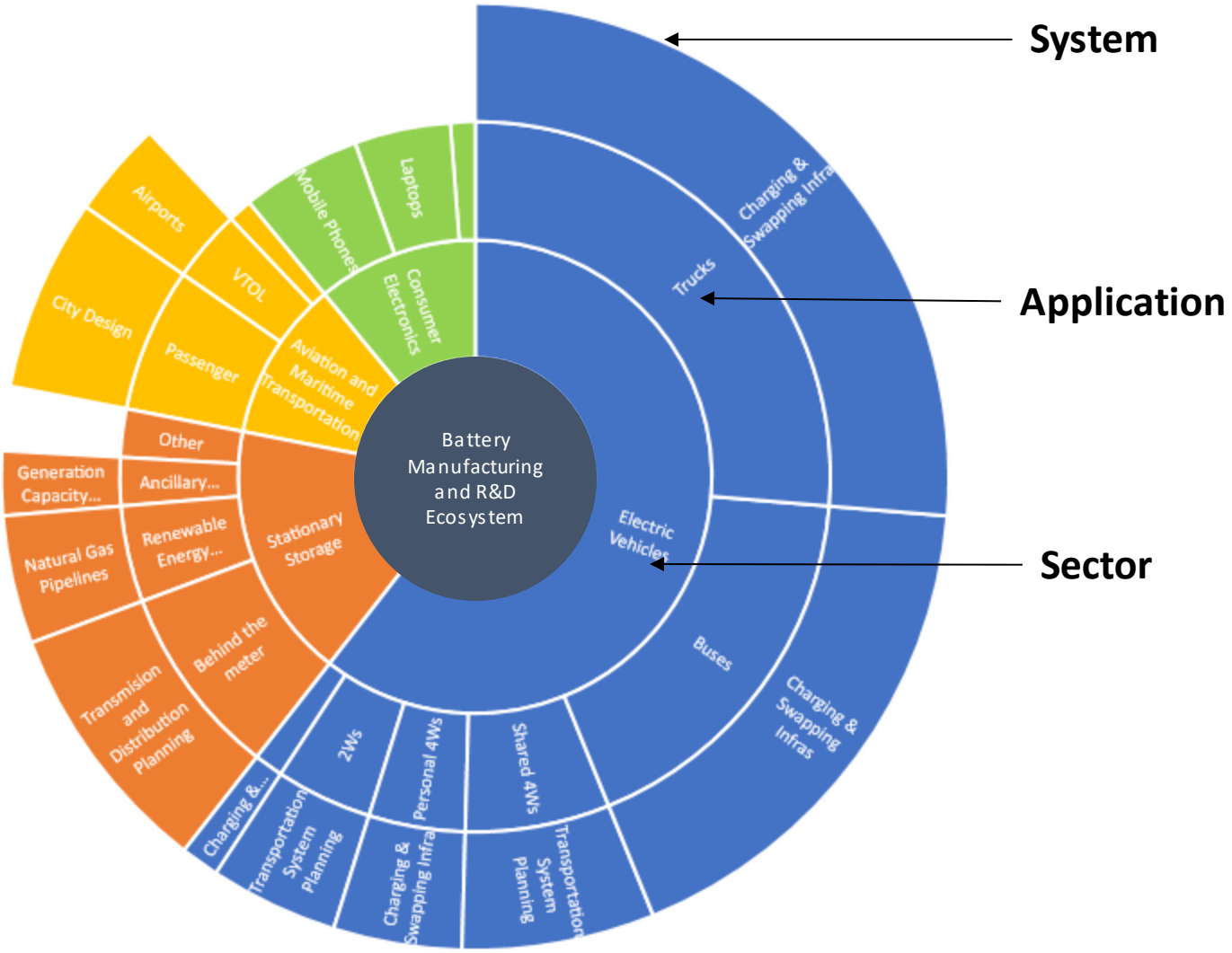
Mobility
Batteries represent 25 – 50% of EV costs. Price reduction will have significant effects on adoption

Electricity
Batteries can provide multiple values to the electric grid, and will play a critical role in integrating an ever growing share of renewables

Maritime Transportation and Aviation
Going forward, batteries may play a key role in decarbonization of these "hard to abate" sectors

Illustrative Representation of Battery Market Potential By Sector

Choice of battery chemistry and architectures will have significant effects on product design and infrastructure planning



Illustrative Representation of Battery Market Potential By Sector

There are reasons to believe that these breakthroughs in battery and storage technologies are achievable

#1: Increased investments in battery startups worldwide: Equity investments in alternative battery technology companies continues to increase. Worldwide investments exceeded $1.5 billion by end of 3Q 2018

#2: Governments are investing in alternative battery technologies: Battery manufacturing is seen as a national energy security priority and governments are providing incentives to alternative battery technologies

#3: Strategic partnerships and investments in battery startups by established players: Diverse players including oil & gas majors, vehicle OEMs, utilities and battery manufacturers are investing in alternative technologies

#4: Advanced methods in material sciences and engineering are reducing time to market for new technologies: These methods allow simulation based testing and rapid prototyping for new materials

#5: New financial instruments are supporting innovative battery and storage technologies: New types of funding and insurance products, that are specifically geared towards cleantech solutions are emerging

#6 Many emerging technologies have been under R&D for an extended period of time and are close to commercialization

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#2 - Governments are investing in advanced battery technologies, as battery manufacturing emerges as a national energy security priority

Japan: LIBTEC

- The Japanese government has created a new research entity—Consortium for Lithium Ion Battery Technology and Evaluation Center (LIBTEC)
- LIBTEC aims to produce a solid state battery with a range of 550 kilometers by 2025 and 800 kilometers by 2030
- The Consortium includes major Japanese vehicle OEMs including Toyota, Honda, Panasonic, Asahi Kasei and Yuasa and research centers at Tokyo University and Kyoto University

Europe: EBA

- The European Battery Alliance (EBA) was launched in October 2017 by Vice President Šefčovič
- It includes the European Commission, several EU countries, the European Investment Bank, key industrial stakeholders and innovation actors including Saft and Northvolt
- It aims to develop a "competitive manufacturing value chain in Europe with sustainable battery cells at its core"

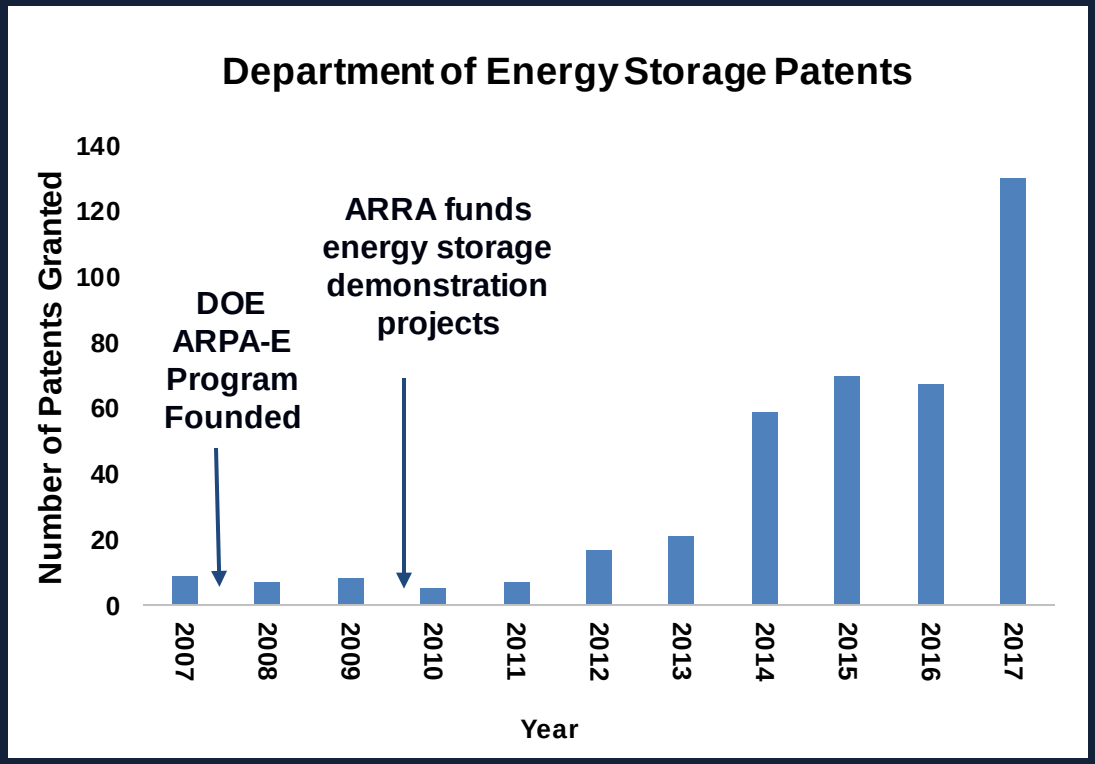
India

- The Indian government recently approved a National Mission on Transformative Mobility and Battery Storage to kickstart domestic manufacturing of advanced batteries
- Domestic battery demand between 2019 and 2030 in mobility and stationary applications is expected to exceed 700 GWh

Germany and France

- France will invest 700 million euros ($790 million) over the next five years into projects to boost the European electric car battery industry
- Germany will put up 1 billion euros ($1.13 billion) towards co-financing battery manufacturing facilities in the country

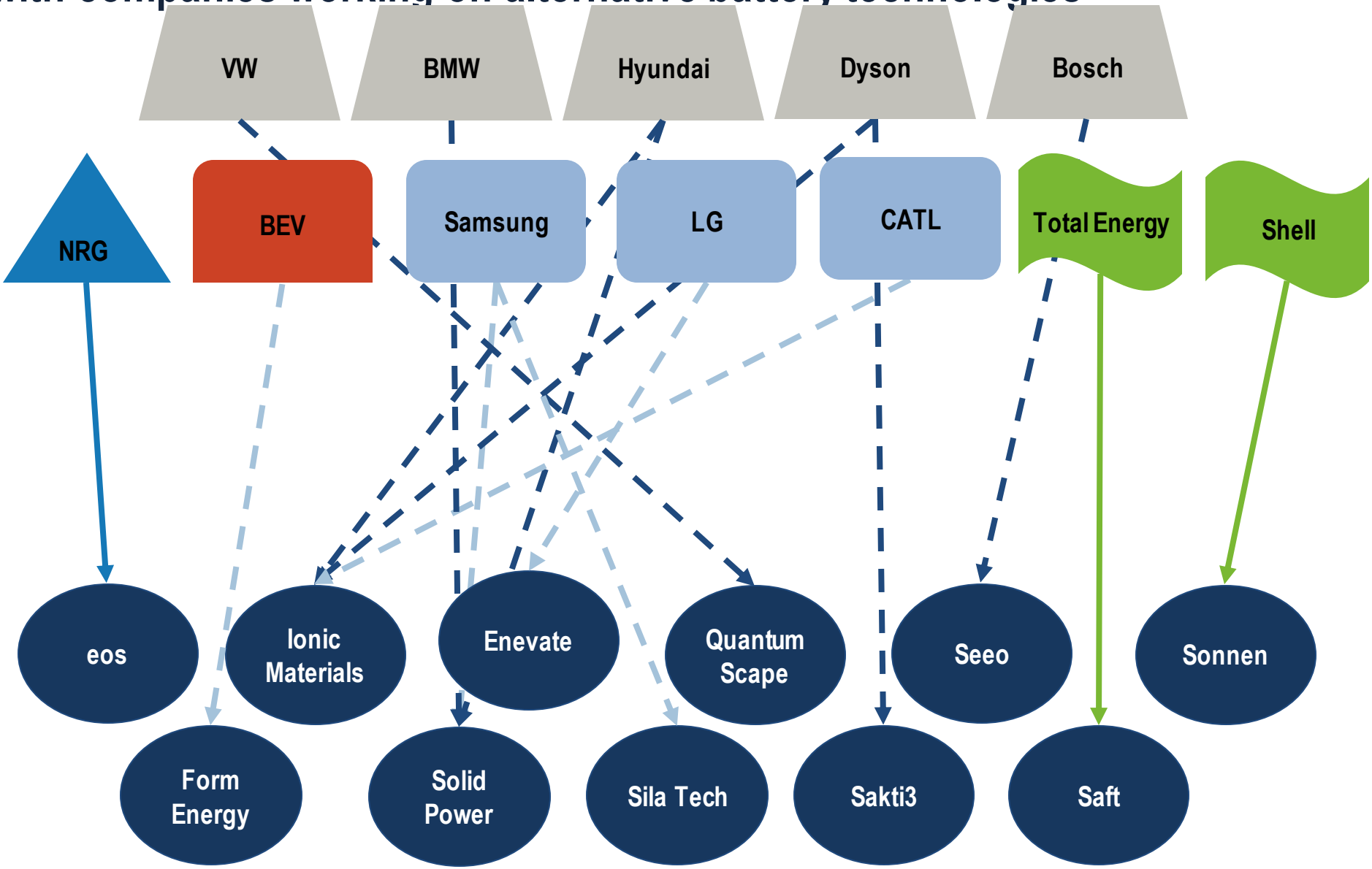
An increase in U.S. government funding contributed to 10x increase in DOE energy storage patents between 2012 - 2017



Energy storage patents resulting from DOE funding

- ARPA-E (Advanced Research Projects Agency - Energy), established in 2007, has invested in high impact storage technologies that are too early for private sector investment
- The American Recovery and Reinvestment Act (ARRA) invested $184 Million dollars, and leveraged an additional $771 Million into storage technology demonstration projects in 2009[1]
- The number of DOE patents has increased from 9 to 130

#3 - A diverse array of players have invested or forged strategic alliances with companies working on alternative battery technologies



However, unlike solar, a diverse and complementary ecosystem of battery technologies is likely to emerge

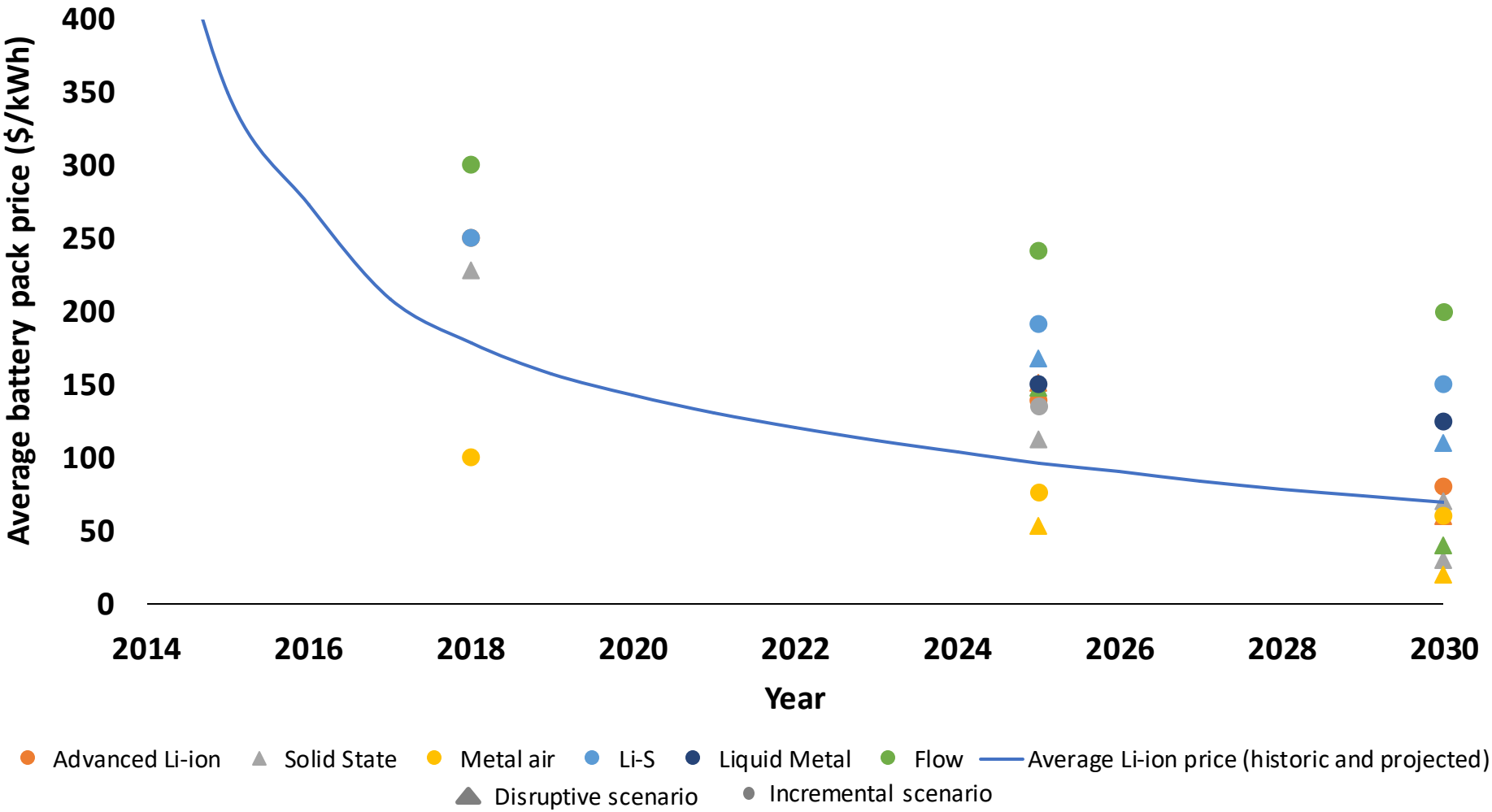
- **Scaling largely trumped innovation in solar panels**
  - Solar piggybacked on engineering and manufacturing developments in the semiconductor and IC industry. Further, emergence of China as the solar manufacturing powerhouse squeezed out competition and innovation in an undifferentiated market

- **But the batteries market is more differentiated because batteries are more closely integrated into the end-uses than solar cells:** Batteries have more diverse attributes (safety, costs and performance), which are valued differently for different use-cases

- **Strong incentives support public and private investments in innovation**
  - Industry has an incentive to invest in R&D to maintain competitive edge
  - Governments need to ensure diverse innovation and localization of the supply chain for reasons around national energy security and economic advantage

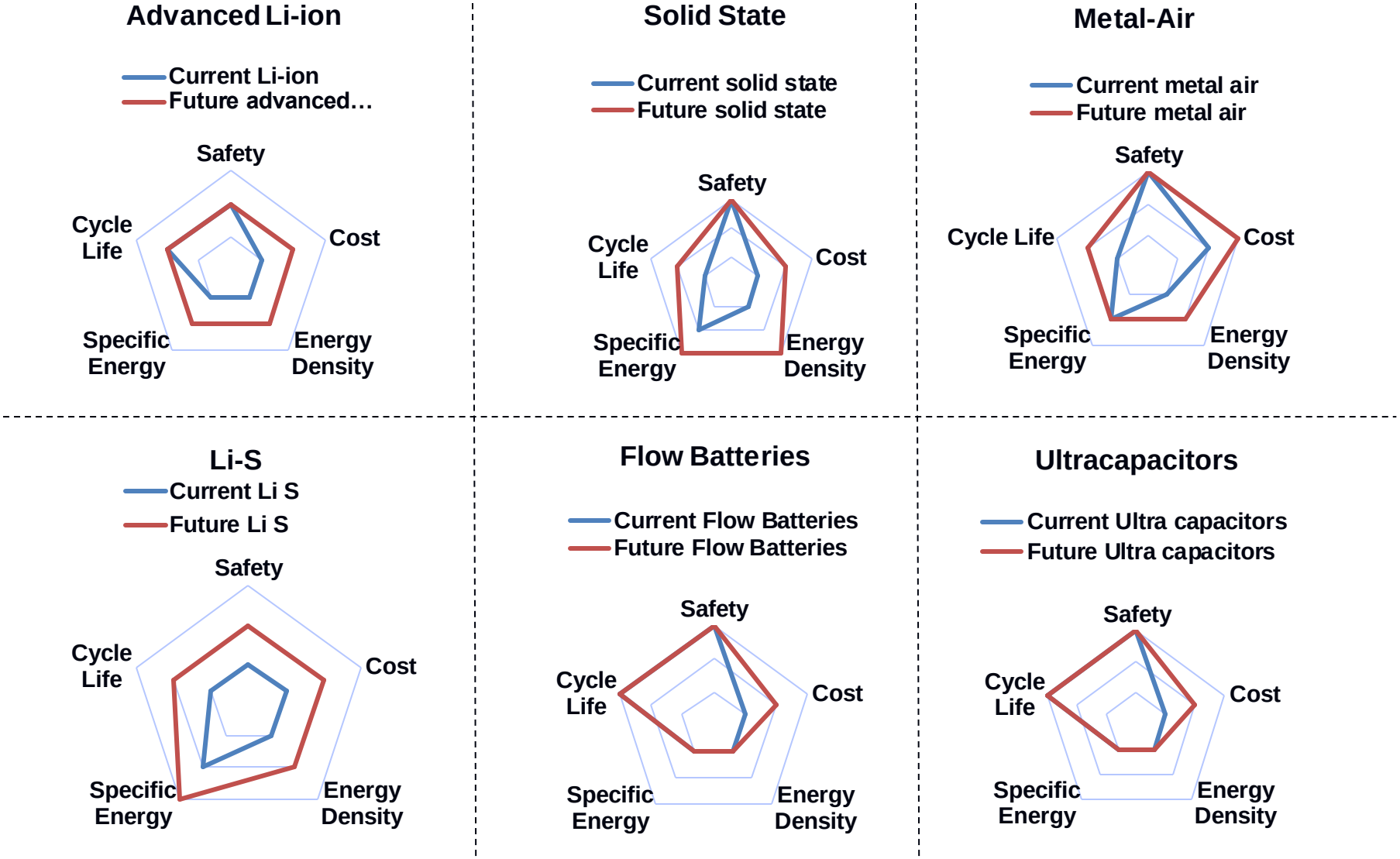
- **Further, battery technologies are likely to become integrated in portfolios that optimally deliver the needed energy services**
  - Delayering to match storage technologies with peak shaving requirements
  - Complementary use of high-power and high-energy batteries in mobility applications to match needs for different attributes during different times in the vehicle's duty cycle

New battery technologies will begin to compete with Li-ion



RMI Research, Bloomberg New Energy Finance

Beyond price, differentiated performance characteristics are likely to determine battery deployments in various applications



RMI Research
Higher/better scores touch the outermost edge, and lower/worse scores the innermost edge.
Example: lowest costs would be at the outermost edge in the radar graphs above.

As costs of solar, wind and storage continue to fall, Clean Energy Portfolios of could outcompete new gas builds

[BNEF] Report: Levelized Cost of Energy for Lithium-Ion Batteries Is Plummeting

gtm:

Xcel Attracts 'Unprecedented' Low Prices for Solar and Wind Paired With Storage

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Florida utility to close natural gas plants, build massive solar-powered battery

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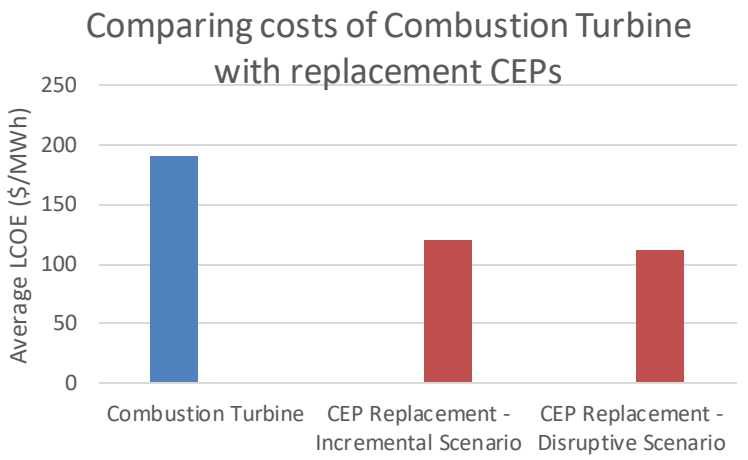
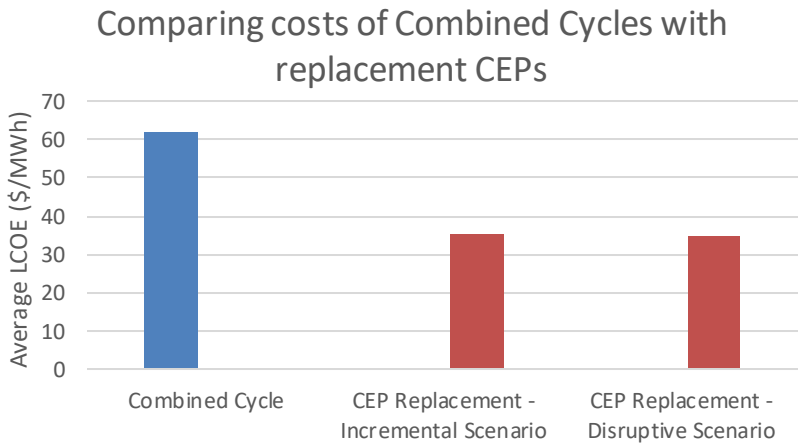
Salt River Project launches first standalone storage project

In 2025:





Preliminary Results

Key takeaways for regulators

	DETAILS	RECOMMENDATIONS
Account for diverse value streams for storage technologies	• Different battery and storage technologies deliver differentiated values • Current electric capacity expansion or planning models may not be able to capture the value of battery and storage technologies	• Hybrid models that can span multi-year planning and sub-hourly operational characteristics may be used for evaluating storage options • Delayering of electricity system services may enable opportunities for new technologies
Technology neutral approach in regulation	• ISO rules in response to FERC 841 that specify restrictive battery discharge durations may inhibit participation of certain battery technologies	• Design regulations with key outcomes and requirements in focus, instead of operational attributes
Data and outcomes from pilots and demonstration projects	• Data around costs and performance of emerging battery technologies may be hard to obtain or verify	• Collect and share benchmarked data on cost and performance from pilots, while respecting commercial interests

STEP CHANGES IN COST AND PERFORMANCE OF BATTERY TECHNOLOGIES ARE LIKELY

Innovations may enable drastic reduction in costs and improvements in performance that current Li-ion technologies cannot achieve. For example, some solid-state electrolytes are likely to enable battery technologies that cost less than $50/kWh. Similarly, other technologies like molten-metal can deliver cycle-life of more than 10,000 without any degradation.

TIMEFRAMES AND PATHWAYS TO COMMERCIALIZATION DIFFER BUT MANY ARE LIKELY IN THE NEAR TERM

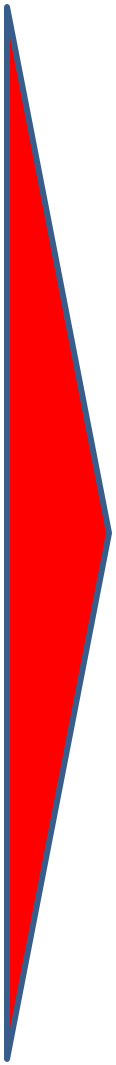
Battery technologies surveyed here are at various stages of commercialization and scaling. Some of these technologies have been tested for specific use-cases but not yet scaling, while others still need additional technology development and prototyping. Public and private sector support can help scale such technologies especially in

ECOSYSTEM OF BATTERIES COULD DELIVER DIVERSE AND COMPLEMENTARY SERVICES

As the markets for batteries evolve and grow, it is likely that niche applications may employ differentiated batteries that are designed specifically around the special needs for that application. It is also likely that different types of batteries, with complementary characteristics may be used in the same application.

BATTERIES WILL HAVE SYSTEM-WIDE IMPLICATIONS

Breakthrough batteries could have implications beyond the application itself, and may affect system design and architecture. For example, electric aviation, which enables near-vertical and low-noise takeoff and landing, may imply that new airports could be located within or closer to cities. This could also have cascading implications on ground-based transportation to and from airports.



MARKET-DRIVEN DECARBONIZATION OF "HARD TO ABATE" SECTORS

Some of these battery breakthroughs could enable electrification and decarbonization of critical ”hard to abate” sectors that contribute nearly 12GtCO2 per year, which is necessary to keep global temperature rise to below 1.5°C.

THANK YOU

Aman Chitkara, achitkara@rmi.org
James Newcomb, jnewcomb@rmi.org