The Rising Stars
The Rising Stars

MODERATED BY
KATIE MCCLAIN
Director, Market Development, Energize Ventures
Cleantech Forum 2019
Rising Stars Session

Matt Harper
President and Chief Product Officer
mharper@avalonbattery.com

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Avalon Overview

Avalon designs, builds and delivers the world’s most dependable flow batteries.

→ MW-scale projects with leading customers in the US and China
→ Externally validated lowest total cost of ownership
→ Targeting the rapidly maturing long-duration, heavy duty cycle storage market.
→ Largest fleet of identical flow batteries ever installed (140+ units in operation)
Avalon’s product: standardization as the path to low cost and reliability

Most flow batteries: Built in place, high construction costs, poor reliability

Avalon flow battery: 13 years’ work yields world’s first turn-key, factory manufactured vanadium flow battery:

Avalon’s highly standardized approach yields:
✓ Proven reliable performance for decades of deep cycles
✓ Economies of scale and quality assurance for entire product
✓ Low-cost, reliable turn-key installation at site
✓ Lowest full-lifecycle total cost of ownership

Result: Durable technology and manufacturing scale yield ultra-low total cost of ownership ($USD LCOS, below)

Avalon 2018: 7.9
Avalon 2025: 2.9
Li-ion 2018: 12.7
Li-ion 2025: 9.9

+61%  +238%

-238%
Avalon established and growing across fastest growing geographies and applications for storage

Current Avalon’s installations

<table>
<thead>
<tr>
<th>Location</th>
<th>Year(s)</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vancouver, BC</td>
<td>2015–2018</td>
<td>125 kWh</td>
</tr>
<tr>
<td>Daejeon, Korea</td>
<td>2017</td>
<td>27 kWh</td>
</tr>
<tr>
<td>Qinghai, China</td>
<td>2018</td>
<td>2 MWh</td>
</tr>
<tr>
<td>Iowa</td>
<td>2018</td>
<td>1 MWh</td>
</tr>
<tr>
<td>California</td>
<td>2016–2018</td>
<td>390 kWh</td>
</tr>
<tr>
<td>Western Australia</td>
<td>2018</td>
<td>50 kWh</td>
</tr>
</tbody>
</table>

Industrial facility in Santa Cruz, CA using solar storage to power facility, avoiding interconnection and energy costs
Avalon Solution: 90kWh, 30kW AFB2
Operational November 2018
IRR (unlevered): 140%

Industrial customer in Pomona, CA using storage to mitigate demand charges and shift energy alongside existing PV array
Avalon Solution: 90kWh, 30kW AFB2
Operational October 2017
IRR (unlevered) 22%

US renewable energy project will use batteries to reduce clipping and optimize plant, boosting energy delivered under PPA
Avalon Solution: 4MW, 16MWh AFB3
Proposal delivered; COD anticipated Q4 2019
IRR (unlevered) 11.3%
Evolution of pipeline over next four years

Avalon Sales Pipeline by Application

Long Run Drivers

- **Microgrid**
  - Huge opportunity in developing world (BRICS+ industrials)
  - Large industrials (eg mines) likely to dominate volume early

- **Behind the meter solar + storage**
  - Continued expansion of BTM sales model
  - Scale of individual projects small

- **Front of meter storage-only**
  - Significant growth as capacity markets expand and business models standardize.
  - Single project size very larger

- **Wind + storage**
  - First projects in China underway; ROW to follow.

- **Front of meter solar + storage**
  - PPA structures in USA starting to require storage as an option.
  - Combination of PPA adder and capacity payments = stable model for growth.
Looking to the future

1. Product Differentiation
   - Longer duration applications gain traction
   - Contract terms will extend beyond 10 years
   - Duty cycles will drive technology specialization

2. Standard Commercial Models
   - Niche and policy-driven projects will be fewer
   - Standardized applications will emerge
   - Standardized financial and contract structures will follow
Product differentiation

Long- and short-duration storage applications will co-exist

AFB3 will better address the 4 - 10 hour segments, which are forecast to be the fastest growing over the medium term.
Product differentiation
Different storage solutions will serve different needs

**Lithium-ion**
- Cost competitive for short-duration applications
- Short life in terms of cycles and years
- Established product with good bankability
  - Best suited for power-focused applications

**Avalon**
- Cost competitive for longer-duration applications
- Long life in terms of cycles and years
- Emerging product with improving bankability
  - Best suited for the energy-focused applications

**Analogy to internal combustion engines**

**Ford EcoBoost M-6007-35T**
- Power: 365 hp
- Cost: 9,600 USD
- Design life: 3,500 hr
- **Specific cost: 26 USD/hp**
  - Best suited for power-focused applications

**Caterpillar CATC 1.1**
- Power: 20 hp
- Cost: 4,000 USD
- Design life: 100,000 hr
- **Specific cost: 200 USD/hp**
  - Best suited for energy-focused applications
Standard commercial models
Low total LCOE = Renewables plus storage as new baseload

Need for new generation capacities due to

Retirement
• Policy-driven retirement of conventional generators
• Retirement of old generators

Flexibility need
• Demand for more dispatchable generators due to high VRE share

Demand growth
• Emerging markets: Overall market growth
• Mature markets: Electric vehicle adoption, etc.

LCOE comparison¹ (USDct/kWh)

1) Values for conventional energy sources based on „Lazard’s levelized cost of energy analysis – Version 11.0“ (Nov 17), see backup slide;
2) Conservative assumption of August 2018 values in EU (17.5 EUR/tCO₂ ~ 20 USD/tCO₂)
3) Assumptions for 2025;
4) Combined cycle gas turbine

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Standard commercial models
Time shifting driven by market price signals

Report:
“Impacts of High Variable Renewable Energy Futures on Wholesale Electricity Prices, and on Electric-Sector Decision Making”

Economical addition of energy storage to VRE possible with increasing share of renewables\(^1\), e.g., at a total share of 40% – expected to be reached between 2020 and 2030 depending on market\(^2\)

1) See following slide for assessment; 2) CleanTechnica (2017) – 50% CAISO renewables target for 2030 expected to be reached by 2020

Profitable operation based on Avalon’s 2025 LCOS of 28 USD/MWh for market-based “time-shift only”
Standard commercial models:
Demand curve getting steeper, increasing opportunities for arbitrage

- Price setting based on marginal cost of most expensive plant ("merit order")
- Increasing share of VRE leading to lower valley prices ("merit order effect")
- Independent from VRE, peak prices may increase, further widening the spread

1) See study results by Berkely Labs on next slides, „High solar” scenario”; 2) Valley and peak price set by marginal costs of most expensive plant that is required („merit order”, see left); 3) Assumptions for 2025

- New VRE and storage assets must be financed based on expected electricity prices, i.e., the applicable price must be higher than the LCOE
- Spreads between peak and valley price that are larger than LCOS make it economically feasible to add storage to VRE and time shift the electricity
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JO-JO HUBBARD
COO & Co-Founder, Electron
Cleantech Forum: Rising Stars

January 29th 2019
Electron thesis

**Mission**
Design and build the digital infrastructure that enables the transition to cheaper, greener, cleaner power

**Infrastructure thesis**
Increasingly complex markets and contractual relationships will be indexed by a shared asset register

**Blockchain thesis**
The coordination mechanism to align incentives and create transparency between market participants
Problem: inability to determine value in increasingly complex systems

1. Data fragmentation
   - Siloed, inconsistent and missing data – no view of the whole system

2. Identity fragmentation
   - Assets with multiple contractual relationships can have multiple identities

3. Market fragmentation
   - Can’t capture most efficient action as impossible to work this out due to the above
Our solution: a shared asset register for attributes & contractual relationships

- Solar PV
- Battery
- Electric Vehicle
- etc...

1. Permissioning and access
2. KYC (root of trust)
3. Provenance (stream of trust)
4. Data Integrity
Our solution: a shared asset register for attributes & contractual relationships

- Capacity
- Location
- Response profile
- Carbon intensity
- etc…
Our solution: a shared asset register for attributes & contractual relationships

- Attributes
- Assets
- Relationships
- Contracts
- Permissions
- Pre-qualifications
- Secondary meters
- etc...
... provides the basis for new markets and services

- Secondary Trading
  - First trade Sep-18 with EDF & UKPR

- Network Capacity
  - In development + market design, UK

- Balancing+ Services
  - Prototyping with 4x Swiss Utilities
Any questions?
Cleantech Forum | San Francisco

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KEVIN NOERTKER
CEO, Ampaire
2019 Cleantech Forum:
Rising Stars
Diversity of Thought

Commercial Electric Aircraft

Kevin Noertker  Co-Founder & CEO
kevin@ampaire.com
The Third Revolution
In Aviation Has Begun
Massive Benefits:
70% - 90% fuel cost savings
25% - 50% maintenance cost savings
Ultra quiet takeoffs and landings
Zero Direct Emissions
Meaningful Impact:
Extended Hours of Operation
More People Will Be Flying
Connecting Communities
Our Mission

- Trusted
- Practical
- Compelling
- Electric Aircraft
Our Vision

Flight are more accessible
to more people from more airports
with electric aircraft that are
safe, clean, quiet and less costly.
Our Flight Plan

Pragmatic

Step-by-step

Lean, Agile, Scalable
The Bottom Line:
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GEORGE PALIKARAS
Founder & CEO, Metamaterial Technologies
Electronics THEN...
Electronics NOW...
Optics has not kept up……
Light
‘Meta’-materials – from the Greek word to go beyond.
Our vision is to democratize nanotechnology and advanced materials.

Metamaterial Technologies mission is to enable every light-using device to manipulate light on demand, at scale and low cost.
We specialize in Large-Area, High-Performance materials at few $/m^2 that can block, absorb and enhance light and can be added to virtually any device.

Design & Prototyping + Proprietary Tools = Scalable & Sustainable Solutions
Disruptive Technology
From 1 million Joules to milli-Joules per cm\(^2\)
Scanning Holography

1200mm Roll-to-Roll
1 meters / min capable
5nm accuracy

Photopolymer Material Matrix  Holographic Patterning  Re-arranged Molecular Structure
Rolling Mask Lithography

- Rolling mask
- UV Light
- Photoresist
- Nano-pattern

- 150nm
- 300mm Roll-to-Roll
- 30 meter / min capable
1. Solar has low Efficiency to Weight Ratio (Watt/kg)

2. Efficiency drops even further without solar tracking

3. High-tech efficient solar panels too expensive ($200+/Watt)
Thin & lightweight – ideal solution for mobility industry
Improves angular absorption – eliminates need for solar tracking systems

1. Moth-eye structures as anti-reflection coatings on glass
2. New transparent metal electrodes to replace ITO
3. Mie scatterers for light trapping in active layer
We aim to produce the world's thinnest Si cells by incorporating metamaterial light trapping coatings to improve light management.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Year</th>
<th>Units in active use (m²)</th>
<th>CO₂ Reduction (kilotons / yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid/EV Cars</td>
<td>2025</td>
<td>14 million</td>
<td>2,265</td>
</tr>
<tr>
<td></td>
<td>2035</td>
<td>110 million</td>
<td>17,000</td>
</tr>
<tr>
<td>Aviation</td>
<td>2025</td>
<td>0.8 million</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>2035</td>
<td>1.9 million</td>
<td>93</td>
</tr>
<tr>
<td>Residential</td>
<td>2025</td>
<td>2 million</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>2035</td>
<td>8 million</td>
<td>480</td>
</tr>
</tbody>
</table>

20 Mton/yr Reduction Potential
Partners
MTI Founded in 2011
Headcount - 46

London, U.K
R&D and EU Sales Office

Dartmouth, Nova Scotia
MTI Corporate HQ
Scaled manufacturing

Pleasanton CA
R&D and USA Sales
Opportunity

$1.8T
Thank you

metamaterial.com
The Rising Stars

JON SOBEL
CEO, Sight Machine
Sight Machine
Unlocking Sustainability in Manufacturing
Manufacturing: The forgotten sector

A pivotal moment

Accomplishing growth

- 16% of Global GDP

Multiplier

- $1.33

75% of private sector R&D

Stalled productivity

Productivity change in the manufacturing sector

<table>
<thead>
<tr>
<th>Year</th>
<th>Average annual change (%)</th>
</tr>
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<tbody>
<tr>
<td>'87-'90</td>
<td>1.6</td>
</tr>
<tr>
<td>'90-'00</td>
<td>3.9</td>
</tr>
<tr>
<td>'00-'07</td>
<td>4.3</td>
</tr>
<tr>
<td>'07-'17</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Source: U.S. Bureau of Labor Statistics

Escalating emissions

- 22% of GHGs

- 29% when indirect energy is taken into account

In clean energy, “industry has been almost entirely ignored”

Rhodium Group
The most promising path lies in data. Manufacturing, a $15 trillion industry, generates the most data of any sector.

If data is oil for the 21st century economy, where would you invest?

"The world's most valuable resource is no longer oil, but data"

Source: Morgan Stanley, IDC, McKinsey Global Institute, World Bank, The Economist
But data remains difficult to use

Operators capture machine data manually

Supervisors and production managers lack actionable information
- Not real-time
- Not automated
- Not comprehensive
- No consistency
The challenge is variety

Incumbent data technology handles data volume and velocity well. Variety remains daunting. Manufacturing is the most extreme environment for variety.

The ideal solution is open, agnostic, and scalable.
Making data useful with the industry’s only AI Data Pipeline and Plant Digital Twin

Acquire

Contextualize & Model

Analyze & Visualize

AI Data Pipeline

Transform and normalize
Data is restructured

Configure Digital Twin of plants, lines, assets, products, and processes

Automated and streaming in real-time
Example: Digitizing manufacturing to improve profitability and reduce carbon footprint

Asian chemicals company (zero waste plant)

- 30 min. reduction in cycle time achieved in first 2 months
- 9% improvement in cycle time achieved in first 2 months
- 40% increase in profitability
- 10-15% decrease in electricity and water use per unit
Example: Digitizing manufacturing to improve efficiency and reduce carbon footprint

- 80% cost is energy
- Complex process due to highly varied products, inputs, and conditions
- Scale company seeking to apply same approach to 25+ plants
- 2%-5% energy reduction through the use of data analytics
The next 10 years: Global scale, every industry
Thank you