

Flywheel Energy Storage System (FESS)

An introduction to mechanical flywheel technology for dispatchable generation in the renewable energy market

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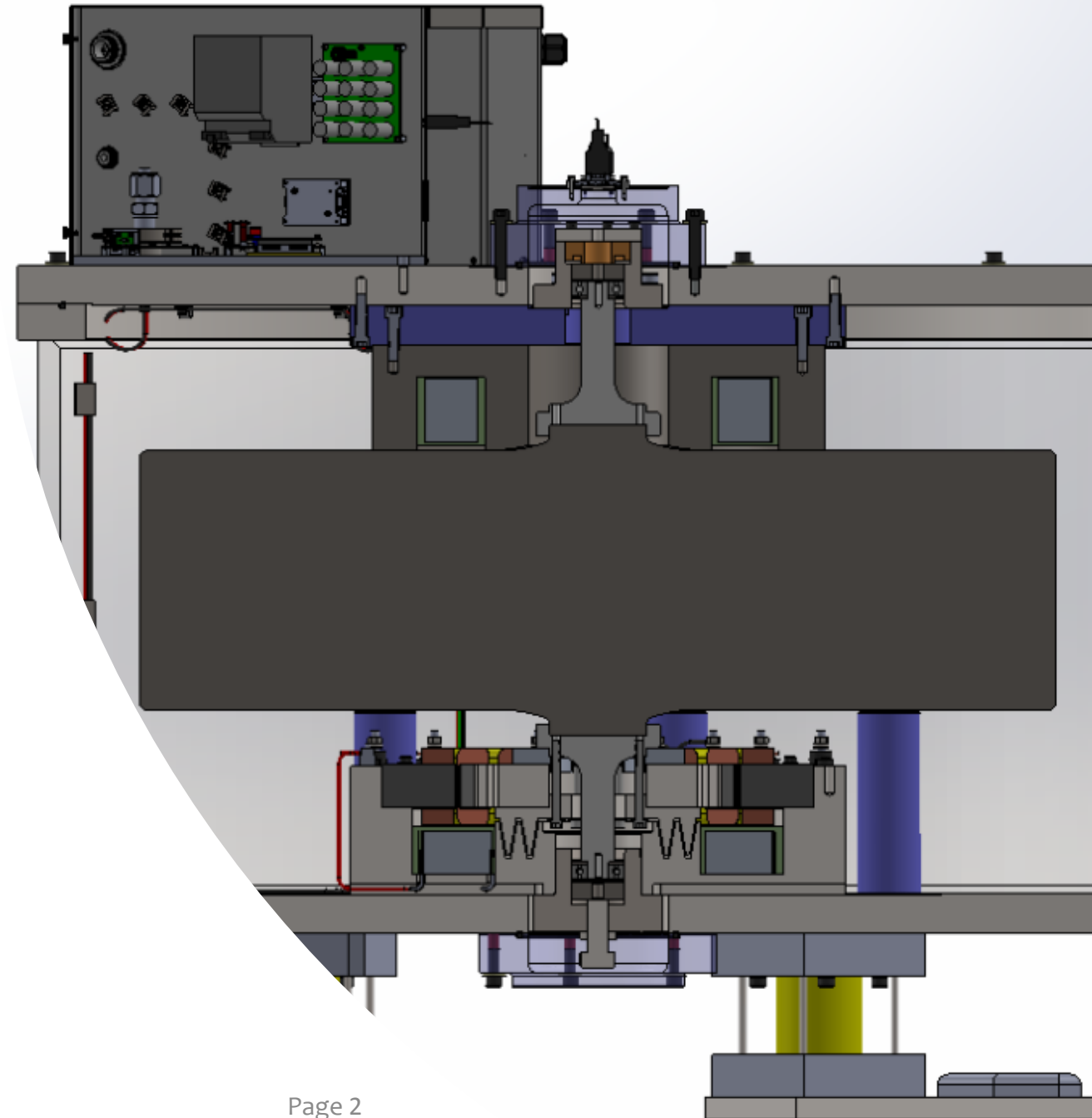


Flywheel Energy Storage System

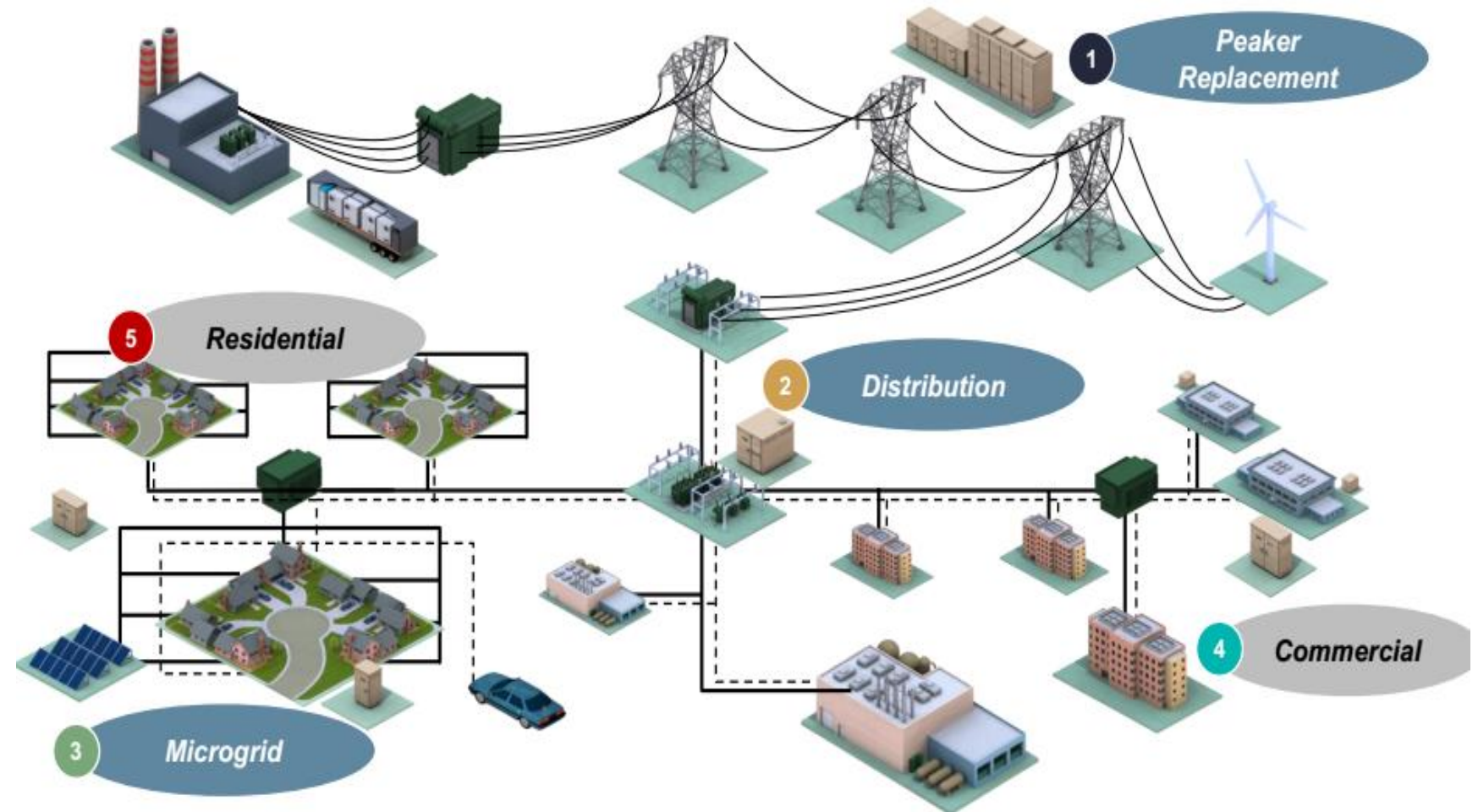


A “mechanical battery”

- Spinning (steel) rotor, with 4 hours duration
- 88% round trip efficiency
- Unlimited cycling
- Less than a second from charge/discharge
- 100% depth of discharge
- 10 year service cycle, 30 year service life
- No end of life environmental challenges
- Stand alone, clusters or utility scale arrays
- 4-Hour Flexible Resource Adequacy
- Load-Shifting / Peak-Shaving, Ancillary Services, Frequency Regulation, Renewable Firming, Spinning Reserve, Micro-grids
- M32 (8kW/32kWh) and M160 (40kW/160kWh)



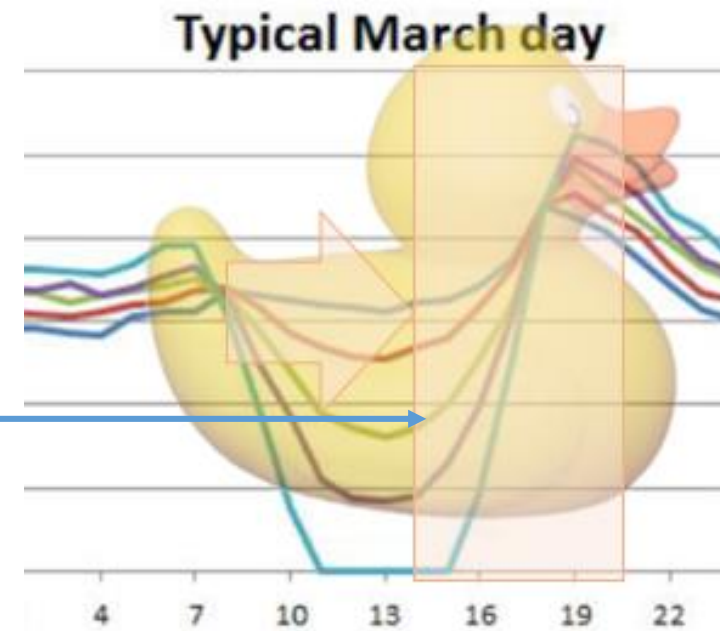
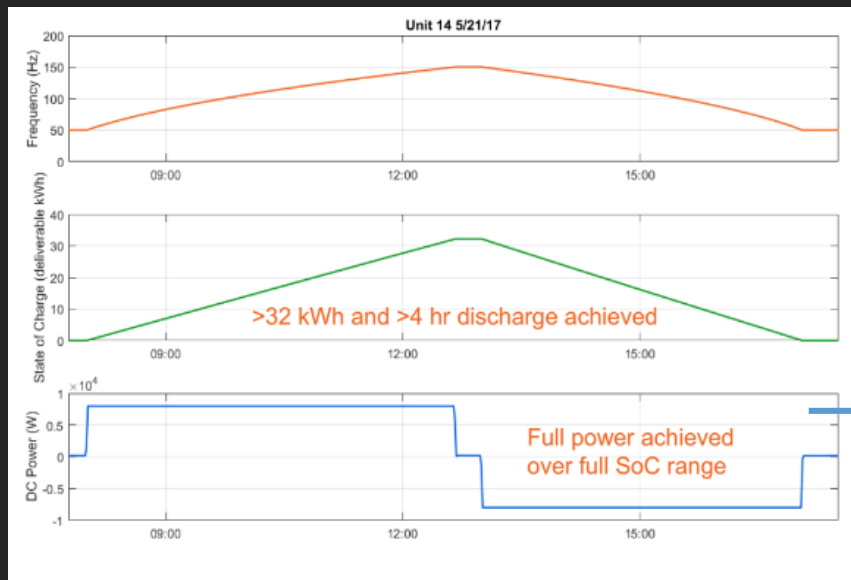
FESS and the Energy Landscape



Source: Lazards Energy, 2017

FESS and the “duck curve”

Dispatchable energy to meet demand



Move energy from daylight to evening; supply to meet demand!

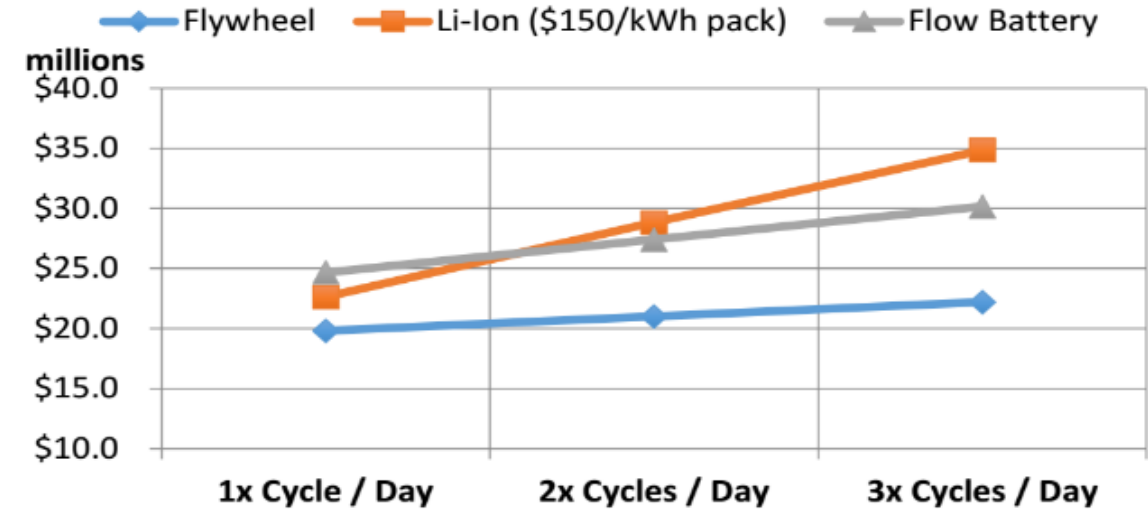
Storage Cost Comparison — LCOS

Part No.	Battery	Cost (\$)	Charger	Capacity (kWh)	Cycles	DoD (%)	Round Trip Efficiency (%)	\$/kWh Capacity	Cost/Cycle (LCOS)	Energy (kWh)	Energy Req to Charge (kW)	Cycles /Day	Life (Years)
Generic	Lead Acid Battery	\$3,100	\$2,300	8.2	2,600	50%	80%	\$659	\$0.253	4.1	10.3	1	7.1
Generic	Li-ion Battery 1	\$3,000	\$2,300	7.0	2,000	50%	92%	\$757	\$0.379	3.5	7.6	1	5.5
Generic	Li-ion Battery 2	\$3,500	\$2,300	10.0	1,500	80%	92%	\$580	\$0.387	8.0	10.9	1	4.1
M32	Amber Kinetics	\$48,000	\$0	32.0	21,900	100%	88%	\$1,500	\$0.068	32.0	36.4	2	30.0
6.5kWh	LG Chem	\$6,780	\$2,300	6.5	6,000	71%	91%	\$1,397	\$0.233	4.6	7.1	1	16.4
ZBM2	Redflow	\$11,400	\$3,500	10.0	3,650	100%	80%	\$1,490	\$0.408	10.0	12.5	1	10.0
RESU10.4	LG Chem	\$6,150	\$2,300	9.8	6,000	85%	85%	\$862	\$0.144	8.3	11.5	1	16.4
PowerWall2	Tesla	\$8,000	\$0	13.5	3,200	100%	90%	\$593	\$0.185	13.5	15.0	1	8.8
Sinnition	(Westside)	\$9,000	\$2,000	6.8	6,000	80%	92%	\$1,618	\$0.270	5.4	7.4	1	16.4

Notes to above

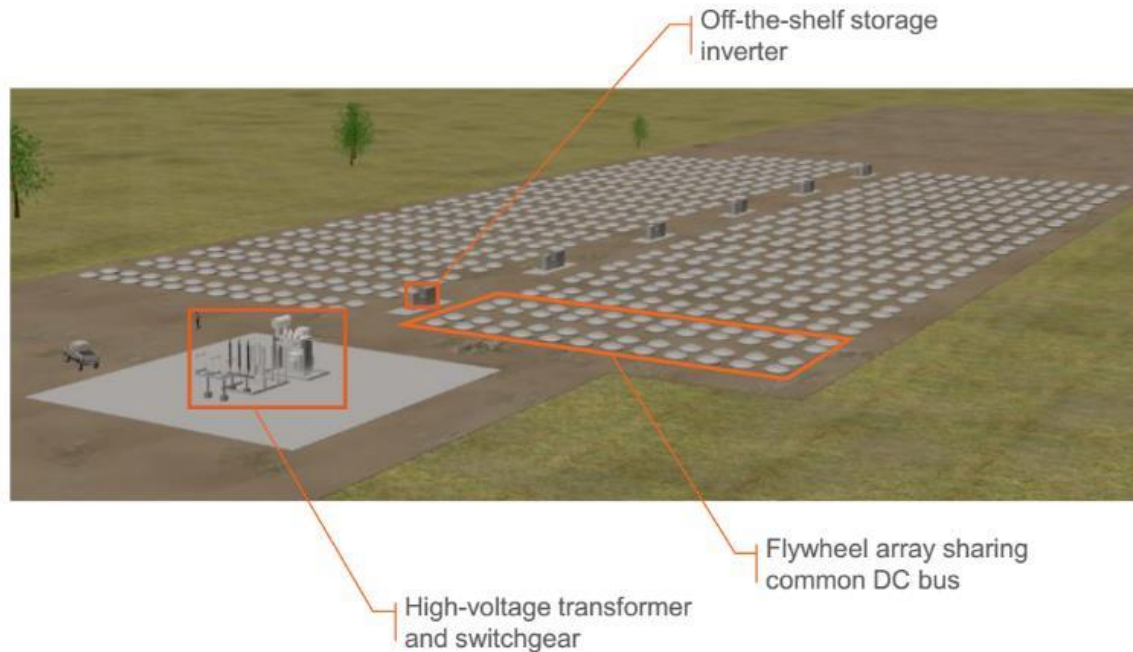
- Developed from published supplier data
- Excludes installation and any tax credits and or subsidies
- LCOS – based on Lazards' Levelised Cost of Storage (LCOS)

10 MW | 40 MWh - Total Cost of Ownership (20-yr NPV)



Based on projected scaled manufacturing and installation pricing models
Amber Kinetics Fresno FESS Proposal 2016

10MW/40MWh FESS Farm Layout



Our FESS Project Development Pipeline

Each stage of development drives;

- Knowledge sharing from each development
- Efficiencies in design, construction and installation
- Production and supply change learnings
- At 25MW SA manufacturing
- Dispatchable generation for ancillary services

M32 FESS;

- M32 product; (8kW/32kWh)
- Dairy SA, 4 unit array, stand alone industrial application
- SA Water; 16 unit array integrated to SA Water management/trading platform



Stage 1 Small Commercial Scale Dairy SA;
32kW/128kWh Storage & demand management, peak shifting



Stage 2 Medium Commercial Scale SA Water; 128kW/500kWh
Demand management
Load shifting



Stage 3 Small Utility Scale;
5 to 10 MW/20 to 40MWh
Ancillary Services
Frequency Control
Arbitrage
Community microgrid (DER Model)



Stage 4 Large Utility Scale Project(s); 50MW/200MWh
Renewable energy generator for NEM supply

M160 FESS;

- M160 product; (40kW/160kWh)
- Possibly SA Water or Light Regional Council; 200 unit array, DER/microgrid community energy model, grid connected with AER, AEMO compliance
- Utility scale; part of a large scale Wind/Solar generator with dispatchable generation for GRO



Thank you

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Array Changing Technologies is **pV magazine's** annual feature demonstrating the latest and greatest technologies in the downstream sector, and looking to reward those with the highest potential to solve a problem, improve performance, lower costs, and push solar forward.

This year, the feature was split into two parts. In June our first three jury members picked out the top 10 from a huge selection of new products and innovations appearing in the European market in the run up to Intersolar Europe, and

then one month later three more industry experts helped us to select the top products appearing in the USA market as Intersolar North America drew near.

Finally, the six jury members came together to pick an overall winner from the two parts. After plenty of deliberation, the field was narrowed and a winner began to emerge alongside some very close runners up. Amber Kinetics M32 Flywheel was chosen as the overall winner, as a tried and tested technology being brought to new scale and applica-

tions. "This is a great concept for energy storage, and combining it with solar PV generation is an innovative idea," says Rebecca Hott of the U.S. Department of Energy, summing up the jury's opinion of the product.

Flywheel storage is certainly not a new concept. However, the jury saw this product's four hour duration with unlimited cycling, as well as the specified lifetime of up to thirty years with little maintenance required, as something truly array changing in its potential.

Array Changing Technologies 2017: A surprise runaway winner to 2017's Array Changing Technologies feature, Amber Kinetics' M32 flywheel storage system impressed the award jury with its potential to provide a practical, chemical-free alternative to lithium-ion storage.

