

# Energy Storage for Sustainable Systems

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# Storage is Needed to

- Buffer temporal variations of loads and sources.
- Provide a constant, predictable source to the grid.
- Provide flexibility during dynamic market conditions.

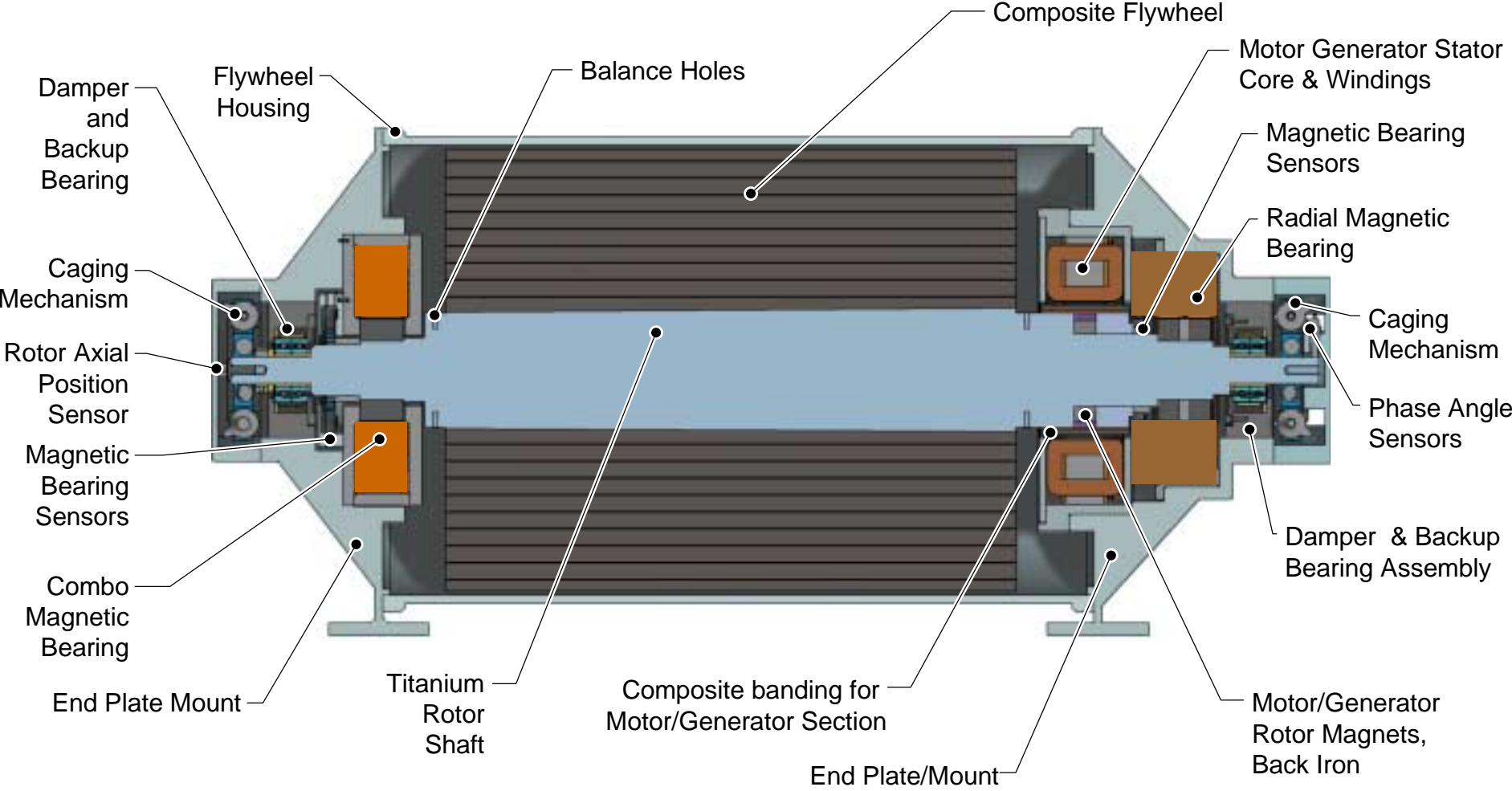
# Energy Storage Systems

- Chemical
- Mechanical
- Electrical

# Current CEM-UT Flywheel Module Design

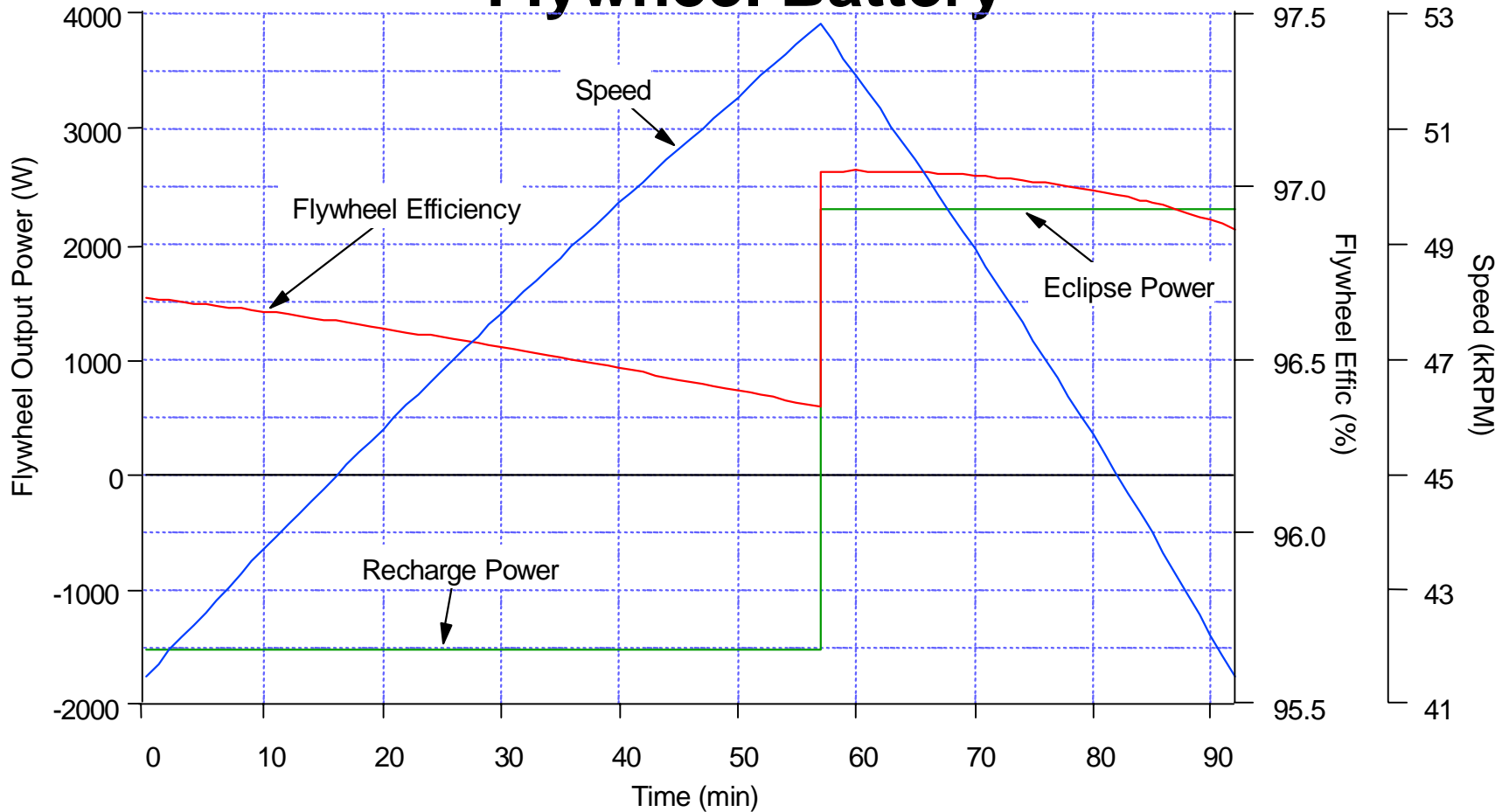
## 3.6 kW, 3.66 kWh, 53,000 RPM

VG 12048.2.ppt



# Nominal Duty Cycle For Space Station Flywheel Battery

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**Turnaround Efficiency=93.7%**

# Comparison of Lead-Acid Batteries, Flywheel Batteries, and SMES

	<b>Lead-Acid Battery</b>	<b>Flywheel Battery</b>	<b>SMES</b>
<b>Storage mechanism</b>	<b>Chemical</b>	<b>Mechanical</b>	<b>Electrical</b>
<b>Life (years in service)</b>	<b>3 – 5</b>	<b>&gt;20</b>	<b>~20</b>
<b>Technology</b>	<b>Proven</b>	<b>Promising</b>	<b>Promising</b>
<b>Number of Manufacturers</b>	<b>~ 700</b>	<b>~ 5</b>	<b>~1</b>
<b>Annual Sales (\$ in millions)</b>	<b>~ 7000</b>	<b>~ 2</b>	<b>A few</b>
<b>Temperature Range</b>	<b>Limited</b>	<b>Broader, but still limited</b>	<b>Controlled</b>
<b>Environmental concerns</b>	<b>Disposal issues</b>	<b>Small</b>	<b>Small</b>
<b>Relative size</b>	<b>Larger</b>	<b>Smallest</b>	<b>Smaller</b>
<b>Maximum time to hold a charge</b>	<b>Years</b>	<b>Hours</b>	<b>Days</b>
<b>Price (\$/kW)</b>	<b>50 – 100</b>	<b>300 – 400</b>	<b>&gt;300</b>

# Research Needs for Flywheel Batteries

- Flywheel Materials
- Magnetic bearings
- Power conditioning