COMPARATIVE STUDY OF **SECONDARY BATTERIES**

Specifications	Lead Acid	NiCD/ NiMH	VRFB (Vanadium)	Lithium-ion (LFP and NMC)	Sodium-Ion	MPGA
Weight Energy Density (Wh/kg)	30-50	45-80/ 60-120	20-40	150-300	140-160	**428**
Power Density (Wh/L): Volumetric energy density	20-50	100-200/ 140-300	40-80	250-300	250-375	**625**
Life Cycle (80% discharge)	200-2,000	2,000-2,500/ 700-1,000	5,000-15,000	500-2,000	5,000+	**45,000**
Life Span (in years)	8	Up to 5	20-25	10	5-10	**20-40**
High Efficiency	70-90%	70%/ 66-92%	80-90%	80-95%	90%	**94.1%**
Fast-Charge Time	8-16h	1-2h/ 2-4h	4-8h	1h or less	15 min	Less than **10 min**
Overcharge Tolerance	High	Low	High	Low, Overheat	Moderate	**High**
Self-Discharge/month (25°C room temp)	10-15% Loss	20-30%	<1%	<10%	1-2%	**<0.3%**
Cell Voltage (nominal)	3.7V	1.2V	1.4V	3.3-3.8V	2.0-3.7V	**3.75V**
Charge Cutoff Voltage (V/cell)	2.40V Float 2.25	Full charge detection by voltage signature	1.75V	4.20V	4.00V	**4.20V**
Discharge Cutoff Voltage (V/cell, 1C)	1.75V	1.00V	1.20V	2.50-3.00V	2.00V	**3.00V**
Charge Temperature	-20 to 50°C (-4 to 122°F)	0 to 45°C (32 to 113°F)	-5 to 45°C (32 to 113°F)	0 to 45°C (32 to 113°F)	0 to 50°C (32 to 122°F)	**-20 to 85°C (-4 to 248° F)**
Discharge Temperature	-20 to 50°C (-4 to 122°F)	-20 to 65°C (-4 to 149°F)	-20 to 50°C (-4 to 122°F)	-20 to 60°C (-4 to 140°F)	-20 to 60°C (-4 to 140°F)	**-20 to 85°C (-4 to 248° F)**
Weight (Kg/1KWh)	20-33kg	12.5-16.7kg	25-50kg	4-7kg	6.6-7.5kg	**2.3kg**
Maintenance Requirement	3-6 Months (topping charge)	30-90 days (discharge)	Not required	Not required	Low Maintenance	**None**
Safety Requirements	Thermally stable	Thermally stable, fuse protection common	Thermally stable	Protection circuit mandatory	Thermally stable	**None**
In Use Since	Late 1800s	1950/ 1990	1995	1996	1990	**2013**
Toxicity	Highly Hazardous Metal and Acid	Caution	Safe	Hazardous	Less Hazardous than Li-Ion	**None**
Cost (per 1KWh)	$100-300	$93-200	$400-800	$130-150	$100-200	**Less than $80**