Batteries

Energy
ITP / NYU / Feddersen

Batteries

Electrochemical energy storage devices. Many materials, chemistries, forms.

No matter how they work, the same considerations apply as for any energy storage:

- Energy per unit volume and mass
- Power per unit volume and mass
- Efficiency – ratio of energy in to energy out

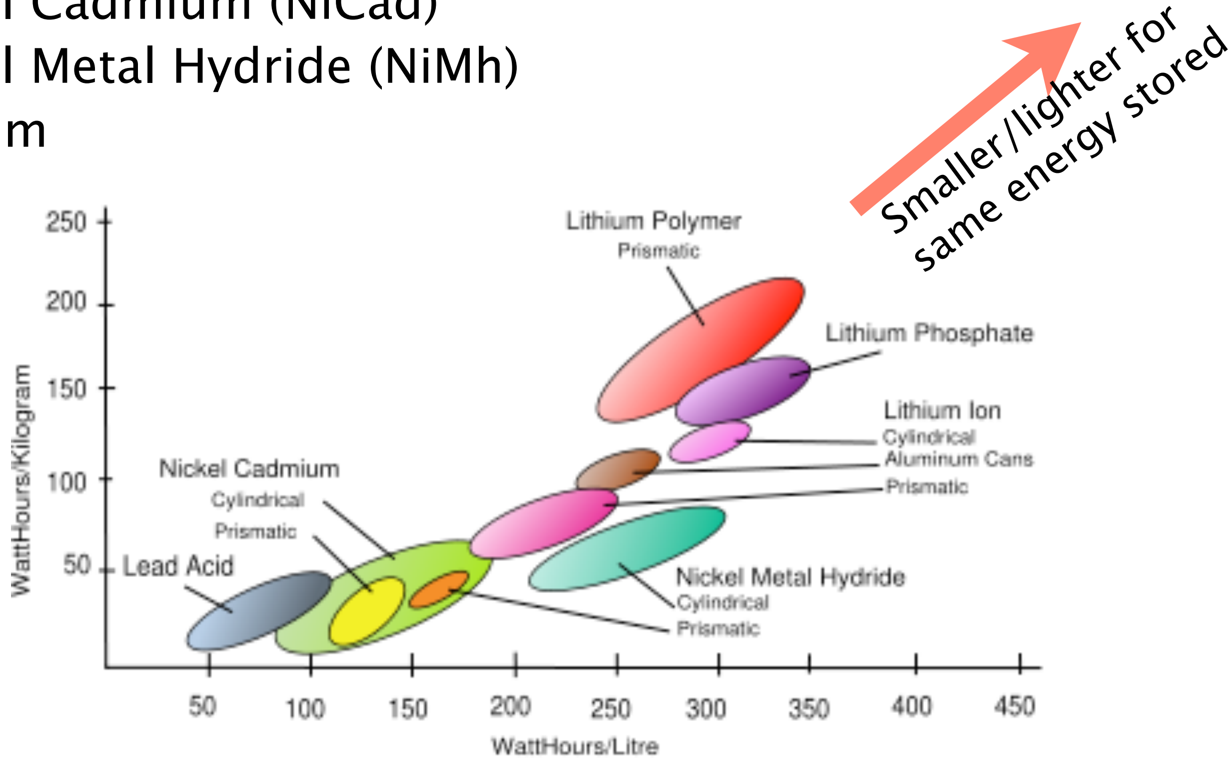
General battery concepts

- "**Cell**" refers to single electrochemical unit; "**battery**" to an array of cells.
- **Voltage** of a cell is intrinsic to chemistry involved; maximum current depends on amount of material (like PV).
- Cells can be arranged in **parallel** to increase maximum **current**.
- Cells can be arranged in **series** to increase **voltage**.
- "**Primary**" = non-rechargeable, "**secondary**" = rechargeable.
- Exceeding maximum or minimum cell voltage will damage the cell (potentially hazardously).

Chemistry – what is the battery made of?

Effects energy density, charging methods, safety considerations, etc. Some common types are:

- Lead acid
- Nickel Cadmium (NiCad)
- Nickel Metal Hydride (NiMh)
- Lithium

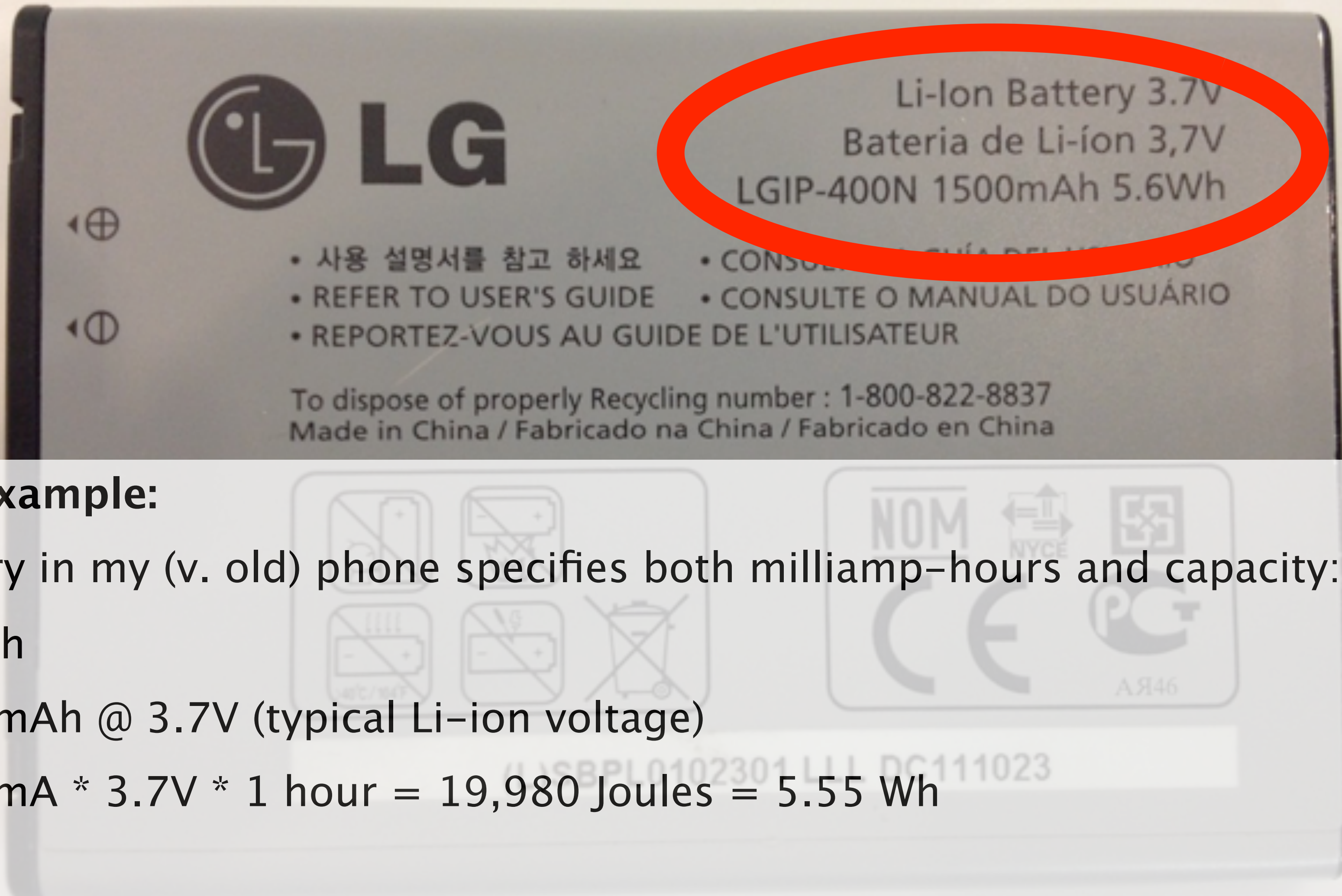


Capacity – how much can the battery hold?

Typically specified in **amp-hours** (or milliamp-hours), abbreviated Ah or mAh.

Can be roughly converted to watt-hours (or Joules) by multiplying amps * 1 hour * nominal voltage.

Capacity – how much can the battery hold?



For example:

Battery in my (v. old) phone specifies both milliamp-hours and capacity:

5.6 Wh

1500mAh @ 3.7V (typical Li-ion voltage)

1500mA * 3.7V * 1 hour = 19,980 Joules = 5.55 Wh

C-Rate

Battery charge/discharge currents are typically given as a **ratio to total capacity** called the **C-Rate.**

For example, for a 750 mA-hour battery:

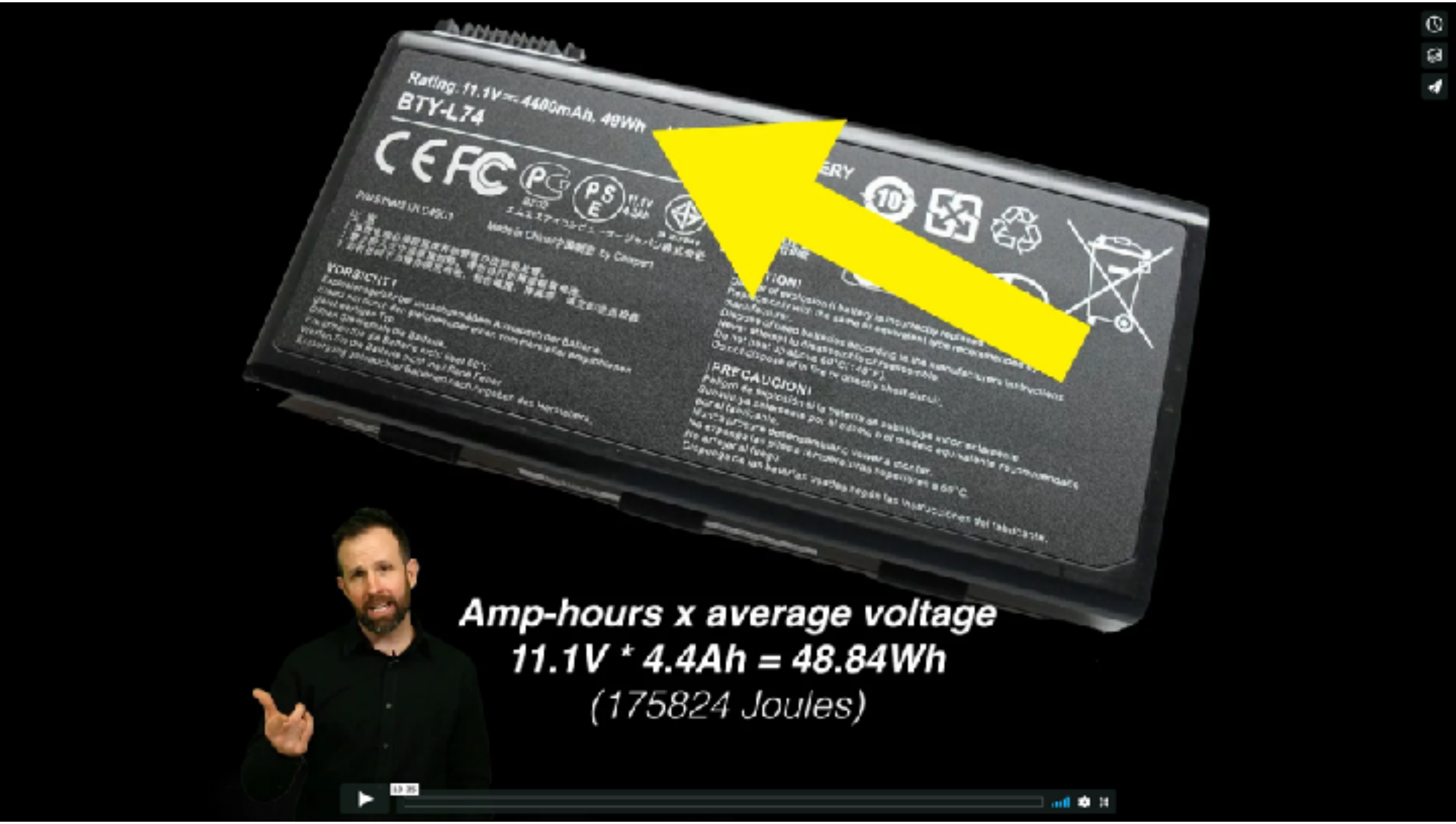
1C = 750mA

2C = 1500mA

.5C = 375 mA

A very important battery specification will be its **maximum safe discharge current.** This will vary widely depending on battery type.

The rated capacity of a battery is (usually) specified for its **C/20 (1/20 C) discharge rate.** Higher or lower rates of discharge may decrease realized capacity.



ITP Energy channel has detailed lecture on Amp-hours and C-Rate

Capacity – technical note

Technical Detail:

Actual capacity depends on how fast the battery is discharged. Discharging a battery very quickly, or slowly, can reduce the realized capacity.

The capacity figure is given for 20-hour discharge rate (C/20)

For example:

A 12 volt battery (~14-10V during use) with a rated capacity of 10 amp-hours could average 12V while supplying 1/2 amp (500 mA) for 20 hours:

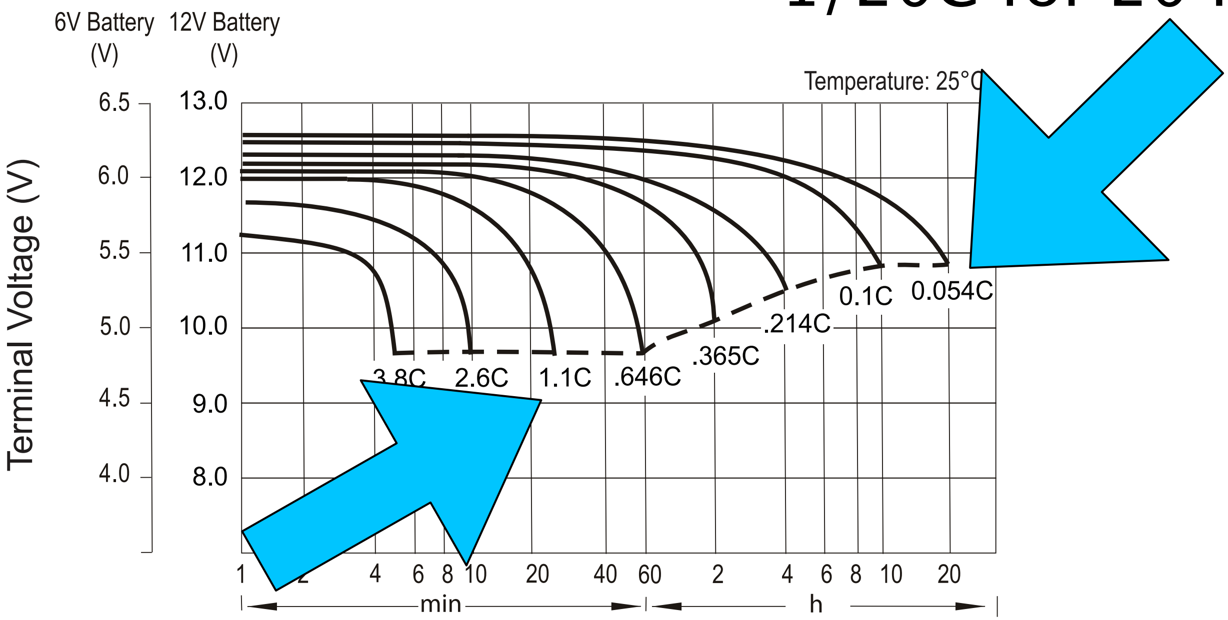
(12 volts) * (500 milliamperes) * (20 hours) = 432 000 joules

More about calculator.

PDC-121100	12	107	100.0	12.99	330	6.81	173	8.46	215	8.66	220
PDC-122000	12	214	200.0	20.55	522	9.45	240	8.58	218	8.82	224

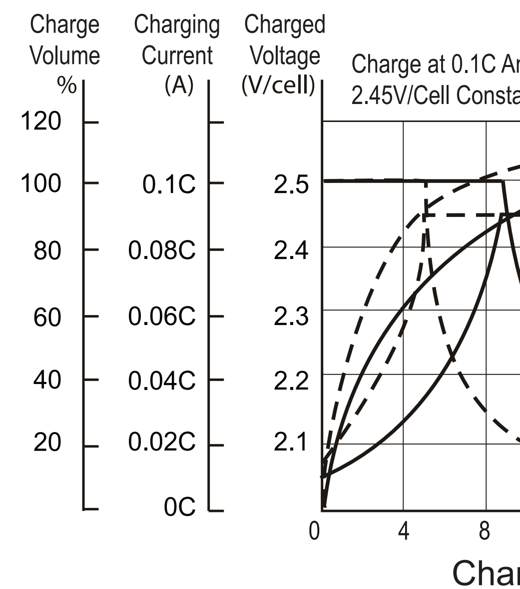
Discharge Characteristics

1/20C for 20 hours OK!



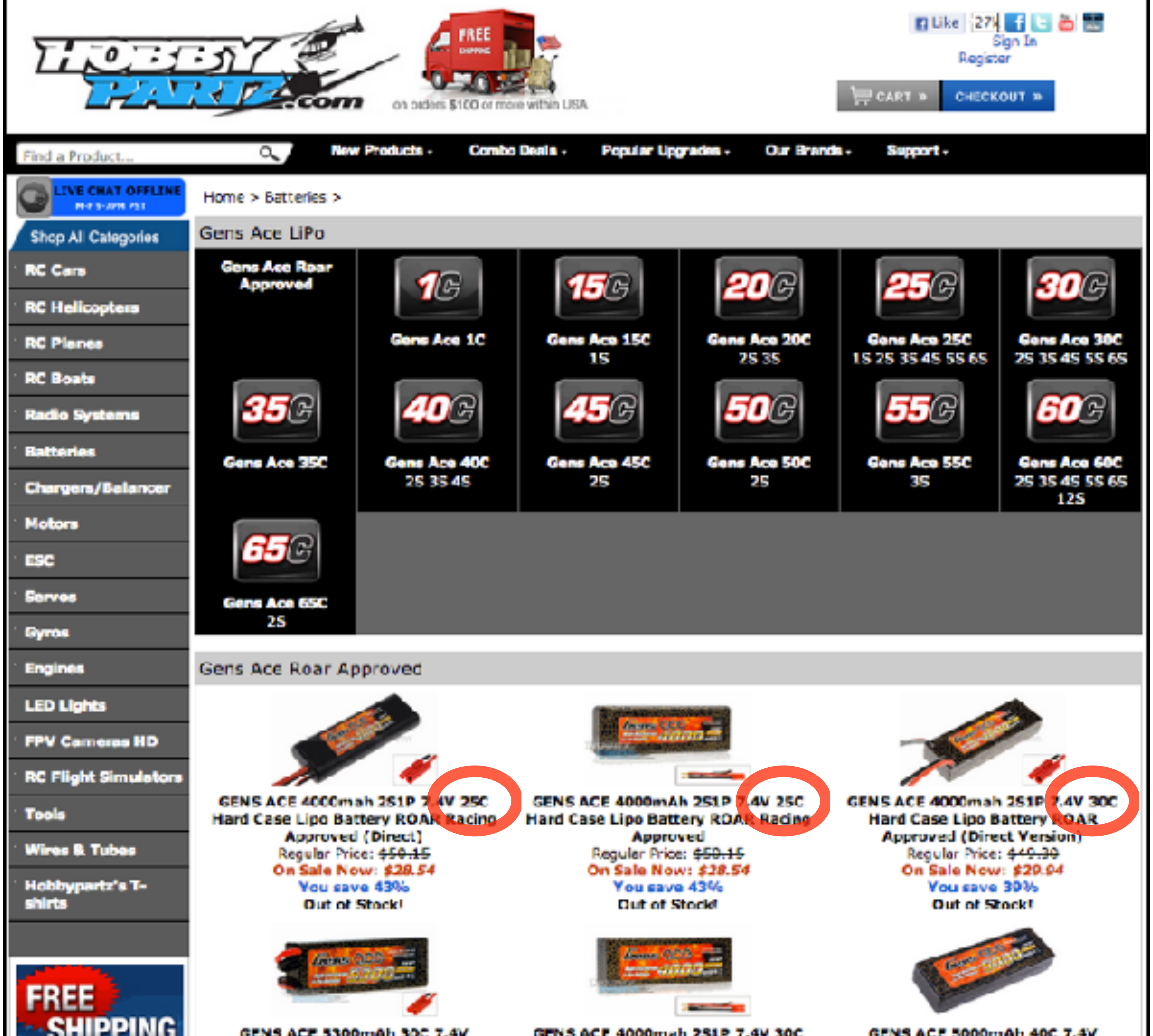
1C for only ~20 minutes, NOT 1 hour

Float Charging Character



Temperature Effects in Relation to Capacity

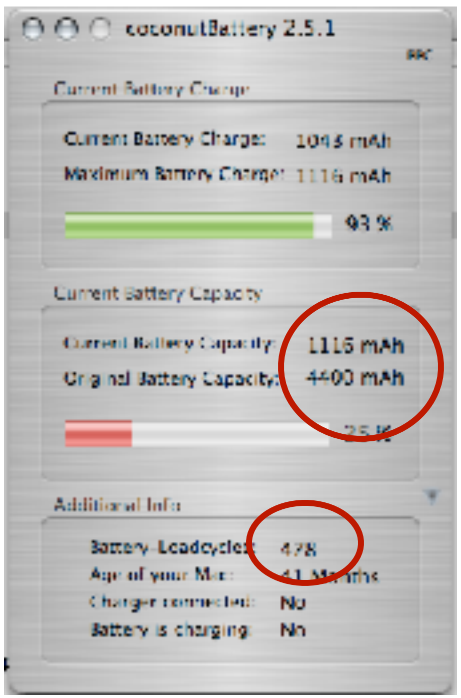
Cycle Life in Relation to D


HobbyPartz.com
FREE SHIPPING
on orders $100 or more within USA
Like 27
Sign In
Register
CART »
CHECKOUT »
Find a Product...
New Products
Combo Deals
Popular Upgrades
Our Brands
Support
LIVE CHAT OFFLINE
Shop All Categories
RC Cars
RC Helicopters
RC Planes
RC Boats
Radio Systems
Batteries
Chargers/Balancer
Motors
ESC
Servos
Gyros
Engines
LED Lights
FPV Cameras HD
RC Flight Simulators
Tools
Wires & Tubes
Hobbypartz's T-shirts
FREE SHIPPING
Home > Batteries >
Gens Ace LiPo
Gens Ace Roar Approved
1C
Gens Ace 1C
15C
Gens Ace 15C
1S
20C
Gens Ace 20C
2S 3S
25C
Gens Ace 25C
1S 2S 3S 4S 5S 6S
30C
Gens Ace 30C
2S 3S 4S 5S 6S
35C
Gens Ace 35C
40C
Gens Ace 40C
2S 3S 4S
45C
Gens Ace 45C
2S
50C
Gens Ace 50C
2S
55C
Gens Ace 55C
3S
60C
Gens Ace 60C
2S 3S 4S 5S 6S
12S
65C
Gens Ace 65C
2S
Gens Ace Roar Approved
GENS ACE 4000mah 2S1P 7.4V 25C
Hard Case Lipo Battery ROAR Racing
Approved (Direct)
Regular Price: $50.15
On Sale Now: $28.54
You save 43%
Out of Stock!
GENS ACE 4000mAh 2S1P 7.4V 25C
Hard Case Lipo Battery ROAR Racing
Approved
Regular Price: $50.15
On Sale Now: $28.54
You save 43%
Out of Stock!
GENS ACE 4000mah 2S1P 7.4V 30C
Hard Case Lipo Battery ROAR
Approved (Direct Version)
Regular Price: $49.30
On Sale Now: $29.94
You save 39%
Out of Stock!

Other considerations:

Battery life – how many times a battery can be charged and discharged. Varies widely by type.

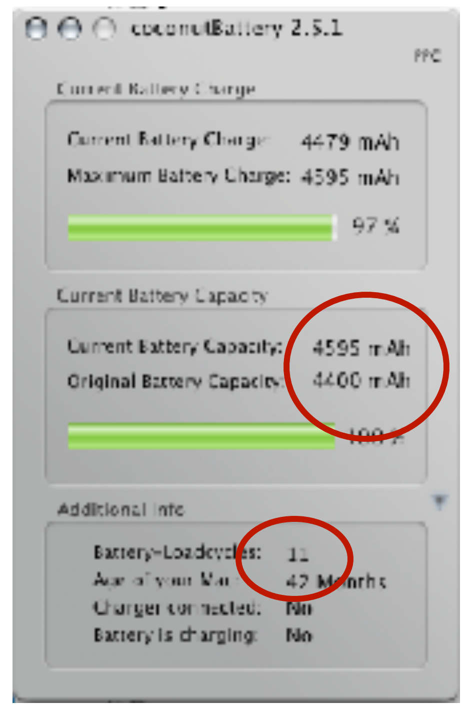
Depth of discharge – how deeply can it be discharged? Decreasing DOD increased life expectancy.



Old Battery

Capacity

Cycles



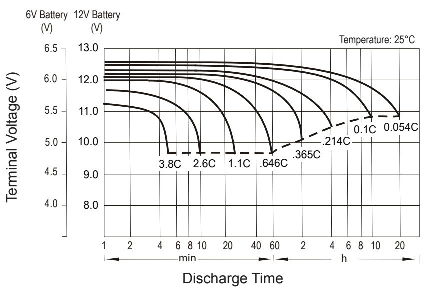
New Battery

Hard to use Voltage alone to determine state of battery since these curves are so flat

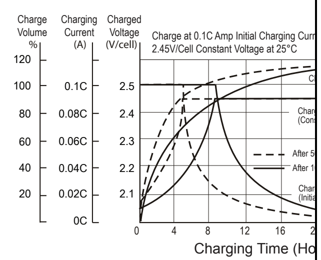
PDC Series - AGM Deep Cycle Batteries

Model	Nominal Voltage	Rated Capacity AH		Length		Width		Height		Total Height		Weight		Terminal Type
		20-hr	10-hr	in.	mm.	in.	mm.	in.	mm.	in.	mm.	lbs.	kgs.	
PDC-1275	12	7.5	7.2	5.94	151	2.56	65	3.72	94.5	3.94	100	5.5	2.5	F2
PDC-1285	12	8.5	8.0	5.94	151	2.56	65	3.72	94.5	3.94	100	6.0	2.7	[illegible]
PDC-12140	12	14.0	13.0	5.96	151.5	3.92	100	3.82	97	3.98	101	9.5	4.3	F2
PDC-12200	12	21.0	20.0	7.15	181.5	3.01	77	6.73	171	6.73	171	15	6.9	B (T12)
PDC-12260	12	28.0	26.0	6.56	166.5	6.89	175	4.92	125	4.92	125	21	9.4	NB
PDC-12260H	12	26.0	24.0	6.50	165	4.92	125	6.89	175	6.89	175	21	9.5	B (T12)
PDC-12350	12	35.0	33.0	7.68	195	5.12	130	6.46	164	7.09	180	25	11.2	NB
PDC-12400	12	40.0	38.0	7.76	197	6.50	165	6.69	170	6.69	170	32	14.5	B (T6)
PDC-12600	12	60.0	55.0	9.04	230	5.45	138	8.27	210	8.66	220	39	17.7	U (T9)
PDC-12800	12	80.0	75.0	10.24	260	6.61	168	8.27	210	9.06	230	50	22.7	U (T14)
PDC-121000	12	100	92.0	12.05	306	6.61	168	8.27	210	8.50	216	61	27.5	[illegible]
PDC-121100	12	107	100.0	12.99	330	6.81	173	8.46	215	8.66	220	67	30.4	[illegible]
PDC-122000	12	214	200.0	20.55	522	9.45	240	8.58	218	8.82	224	138	62.5	[illegible]

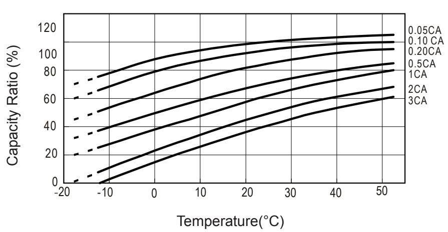
Discharge Characteristics



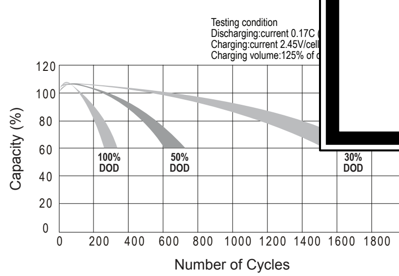
Float Charging Characteristics

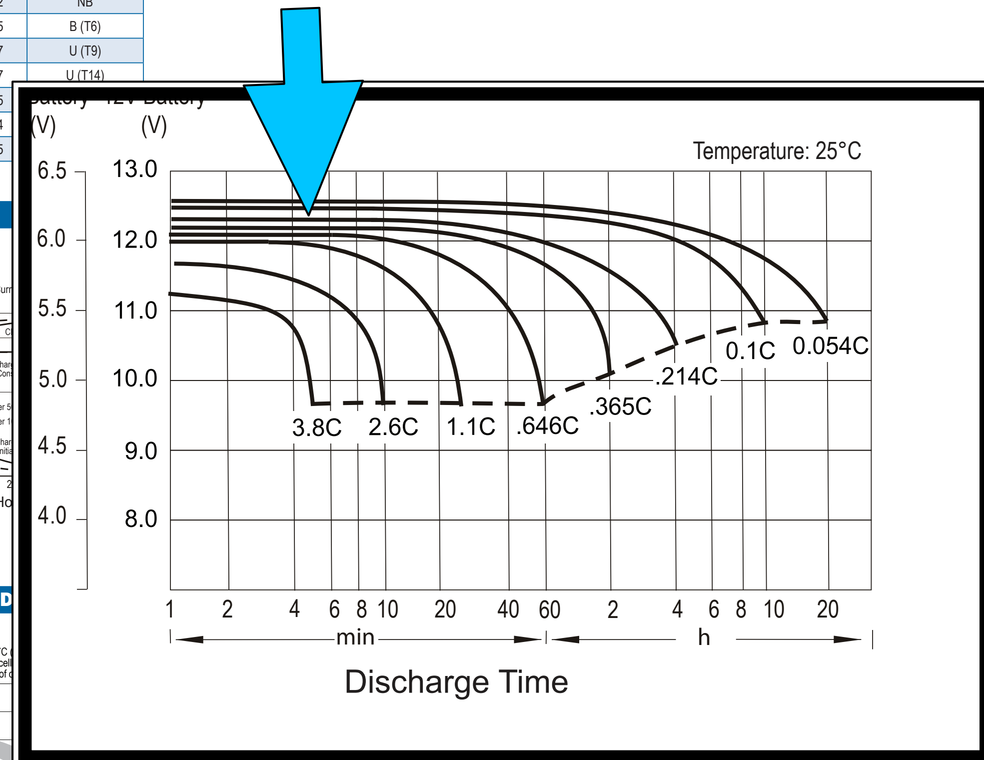


Temperature Effects in Relation to Capacity



Cycle Life in Relation to Depth of D





Contact Information **www.power-sonic.com**

DOMESTIC SALES
Tel: +1-619-661-2020
Fax: +1-619-661-3650
national-sales@power-sonic.com

CUSTOMER SERVICE
Tel: +1-619-661-2030
Fax: +1-619-661-3648
customer-service@power-sonic.com

TECHNICAL SUPPORT
Tel: +1-619-661-2020
Fax: +1-619-661-3648
support@power-sonic.com

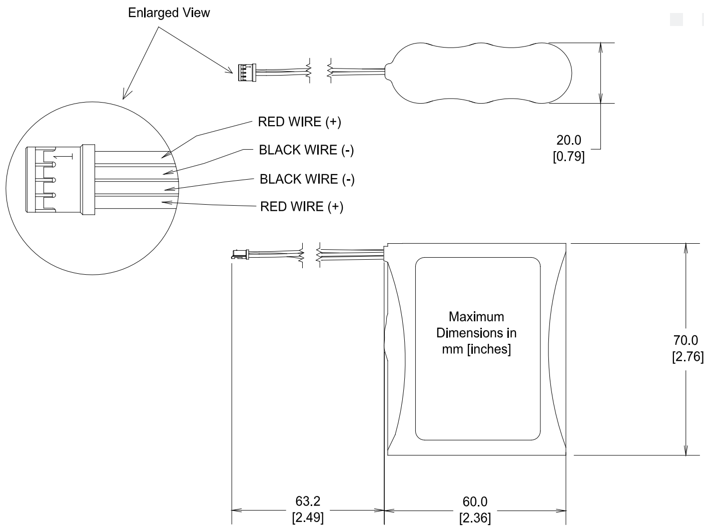
INTERNATIONAL SALES
Tel: +1-650-364-5001
Fax: +1-650-366-3662
international-sales@power-sonic.com

CORPORATE OFFICE • 7550 Panasonic Way • San Diego, CA 92154 • USA • Tel: +1-619-661-2020 • Fax: +1-619-661-3650

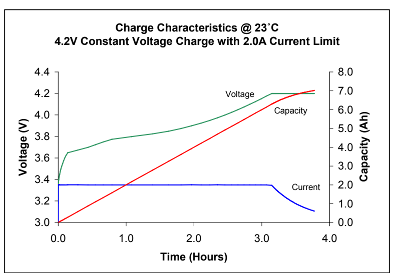
0912 1M

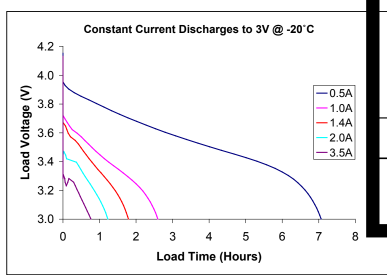
A little better… still need to know current in real time

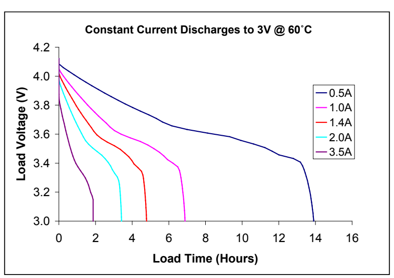
Dimensions

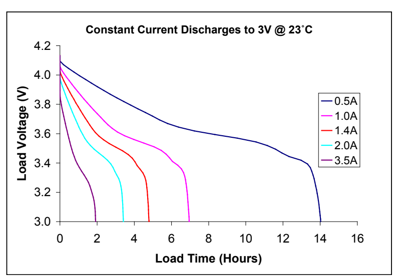


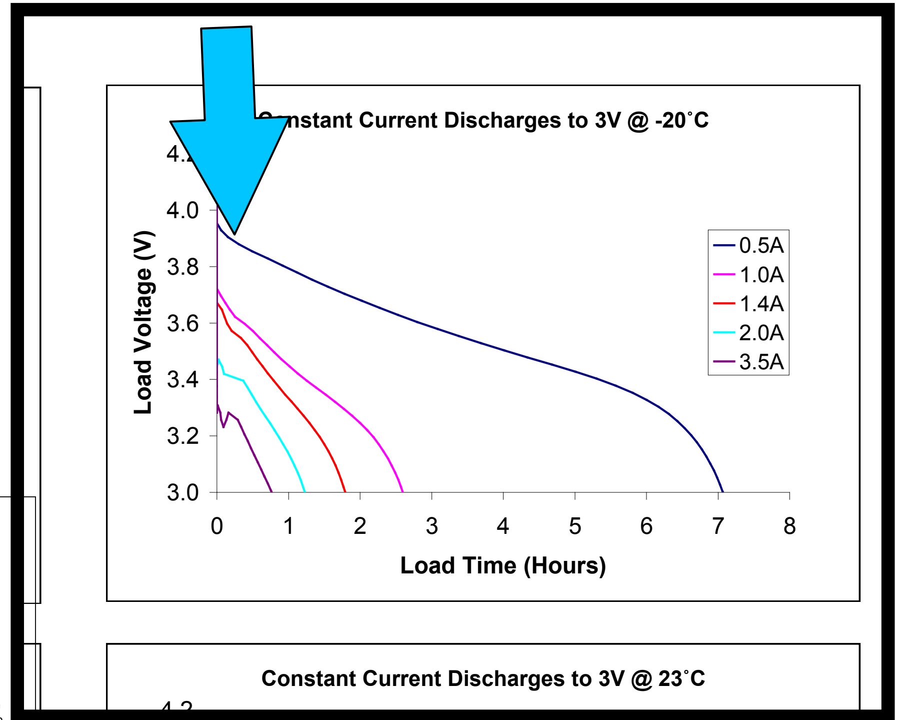
Performance Graphs









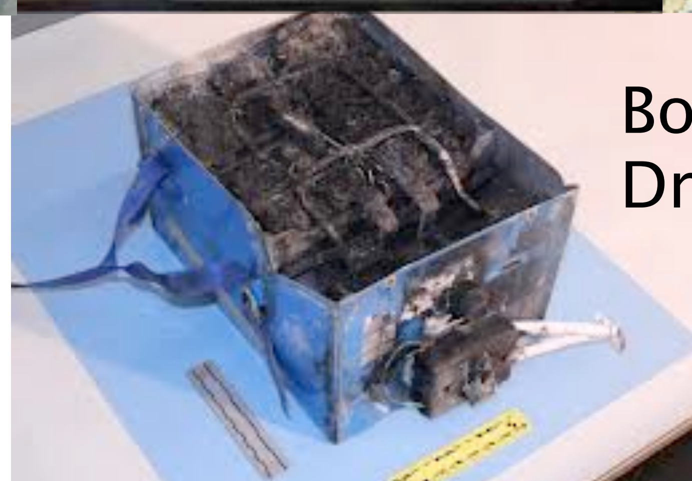


Newark, New York | 315-332-7100 | Fax: 315-331-7800

Charging

Charging batteries can be very complex.

Doing it wrong can be dangerous!



Boeing Dreamliner

and the list goes on…
(Note 7, Hoverboards…)


屏

Charging – the hard (high performance) way

In order to maximize battery performance (most energy over longest time in smallest, lightest package) complex battery monitoring and charging circuits and algorithms are used.

They take into account:

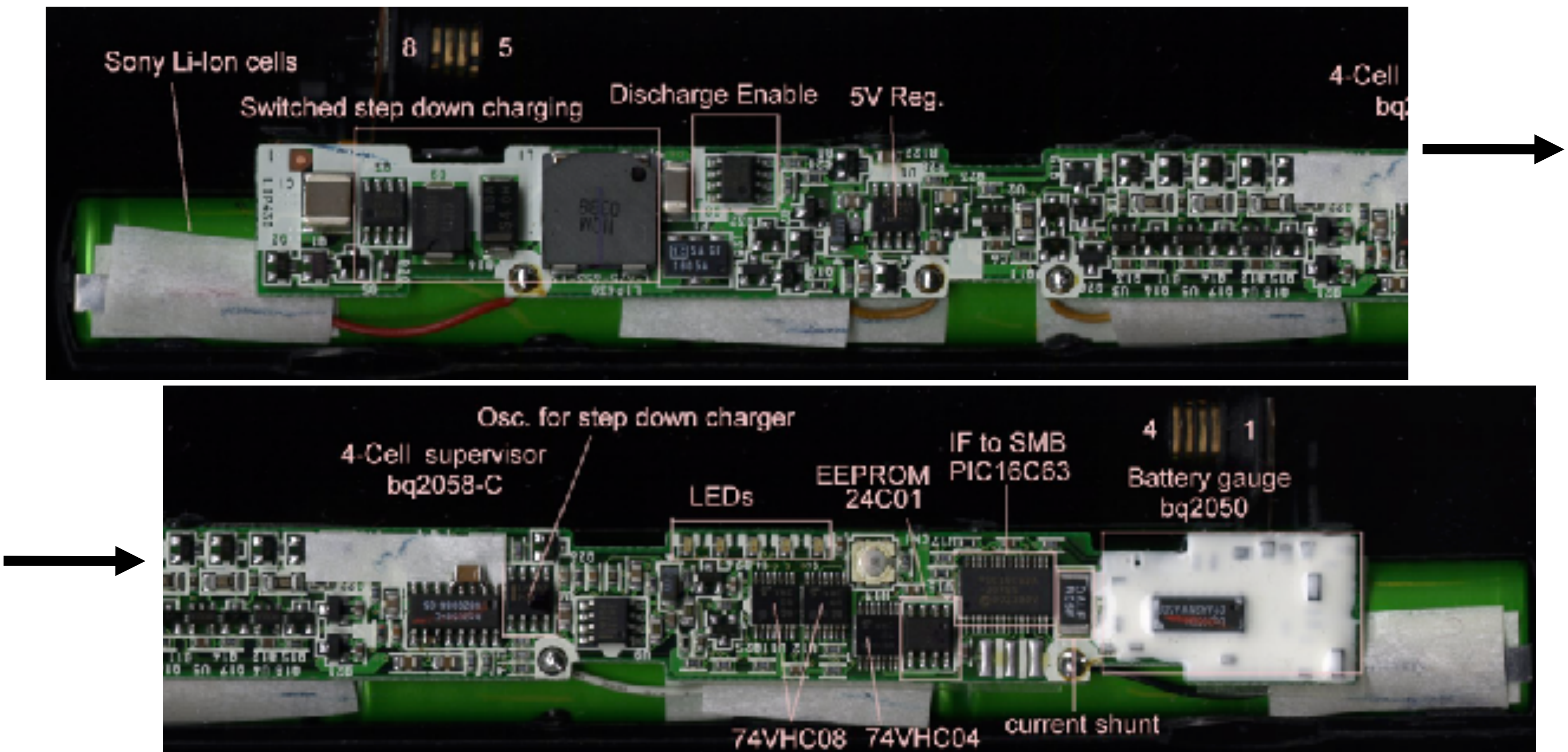
- Complete charge/discharge history of battery
- Temperature
- Battery age

An advanced system typically uses a combination of **constant current** and/or **constant voltage** charge stages coupled with **current, delta V, and/or delta T monitoring** (changes in the rate of change of voltage or temperature). These will be tailored to the battery chemistry, number of cells, and other considerations. Term of art is "**coulomb counting**"

Charging – the hard (high performance) way

Many manufacturers (Maxim, Analog Devices, etc) make dedicated battery ICs. (And publish whitepapers covering charging specifics)

The “Smart Battery” standard includes microcontrollers in the pack to communicate battery state to host device.



Panasonic

Lithium Ion
NCR18650PF

Features & Benefits

- High energy and power density
- Long, stable, high power density
- High safety performance
- Ideal for power assisted bicycles, 2-way radios, medical devices and robotics.

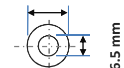
* At temperatures below 10°C, charge at a 0.25C rate.

Specifications

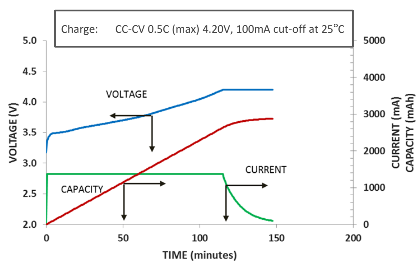
Rated capacity[(1)]	Min. 2700mAh
Capacity[(2)]	Min. 2750mAh Typ. 2900mAh
Nominal voltage	3.6V
Charging	CC-CV, Std. 1375mA, 4.20V, 4.0 hrs
Weight (max.)	48.0 g
Temperature	Charge*: 0 to +45°C Discharge: -20 to +60°C Storage: -20 to +50°C
Energy density[(3)]	Volumetric: 577 Wh/l Gravimetric: 207 Wh/kg

[(1)] At 20°C [(2)] At 25° C [(3)] Energy density based on bare cell dimensions

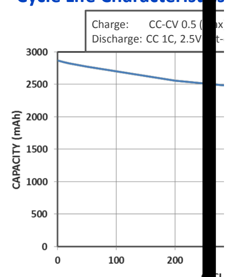
Dimensions



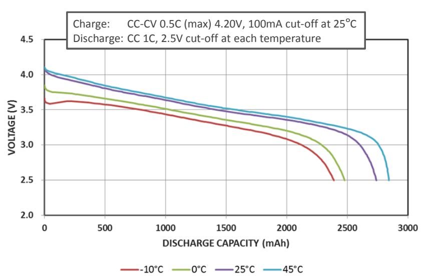
Charge Characteristics



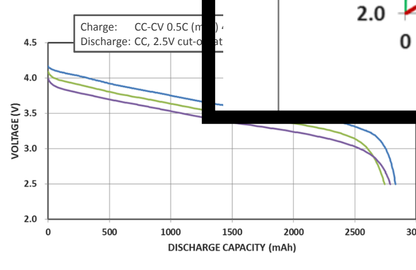
Cycle Life Characteristics

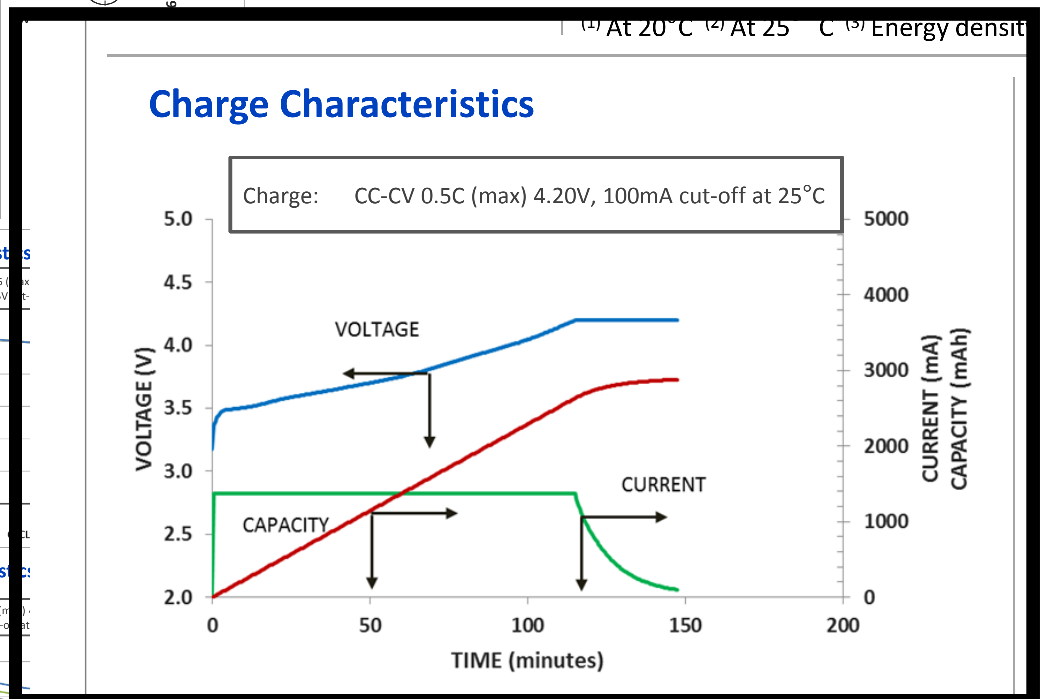


Discharge Characteristics (by temperature)



Discharge Characteristics



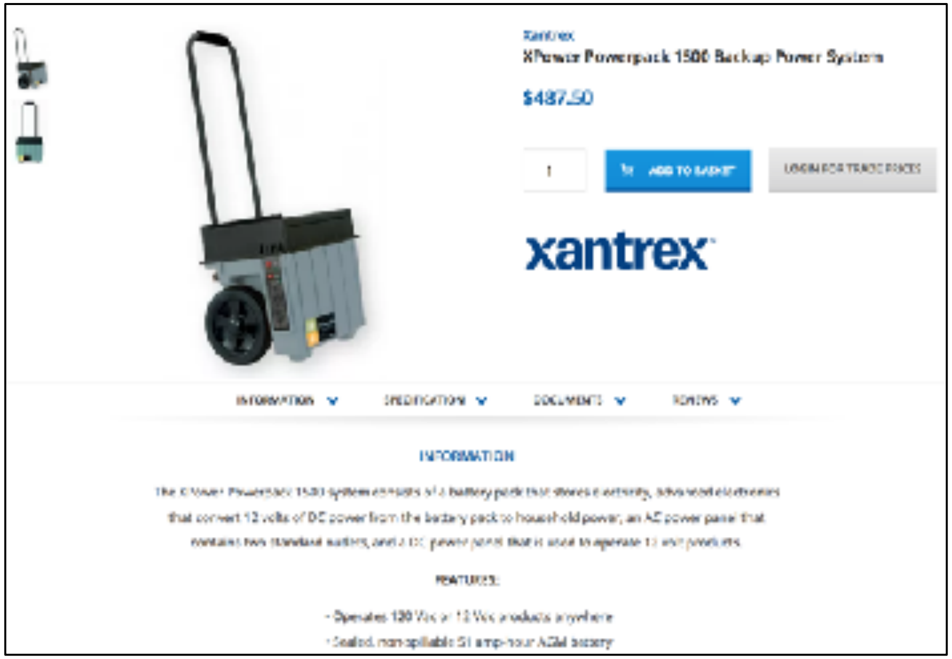


The data in this document is for descriptive purposes only and is not intended to make or imply any guarantee or warranty.

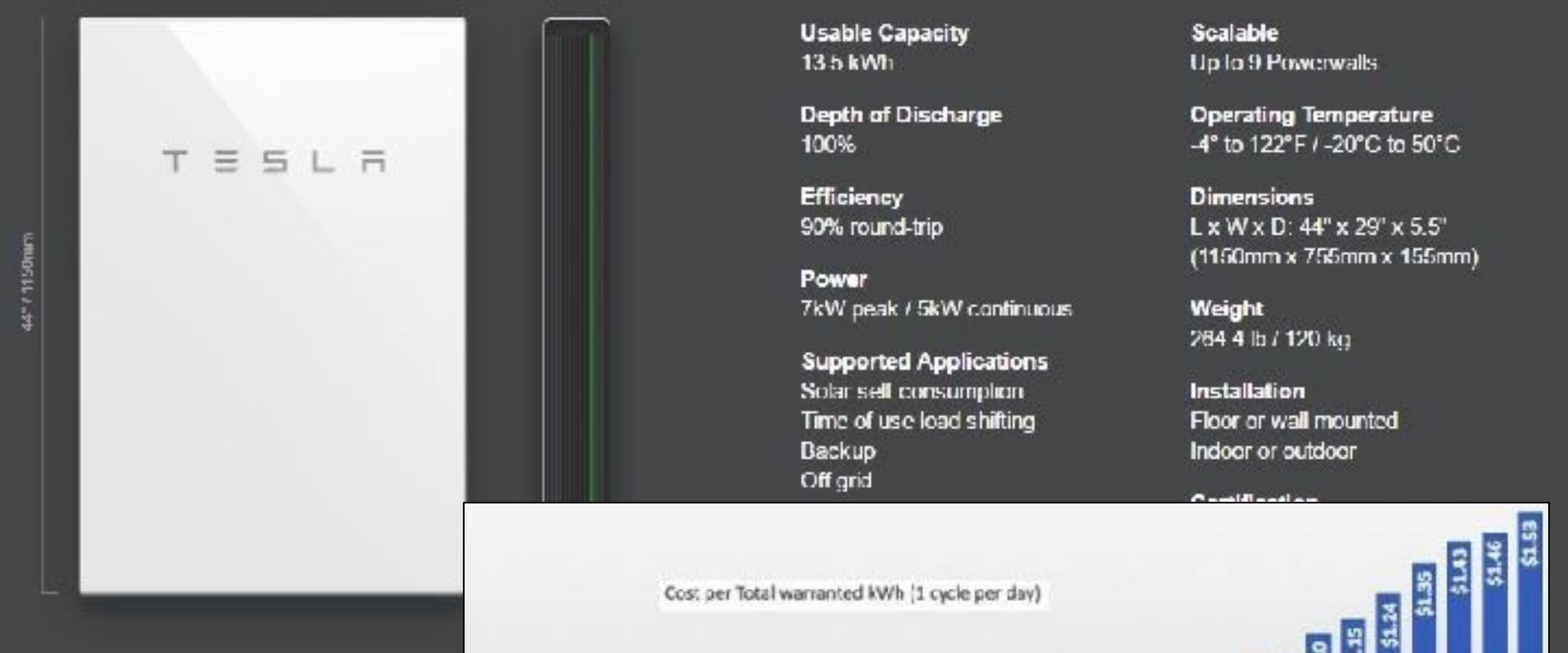
~1Wh AAA alkaline

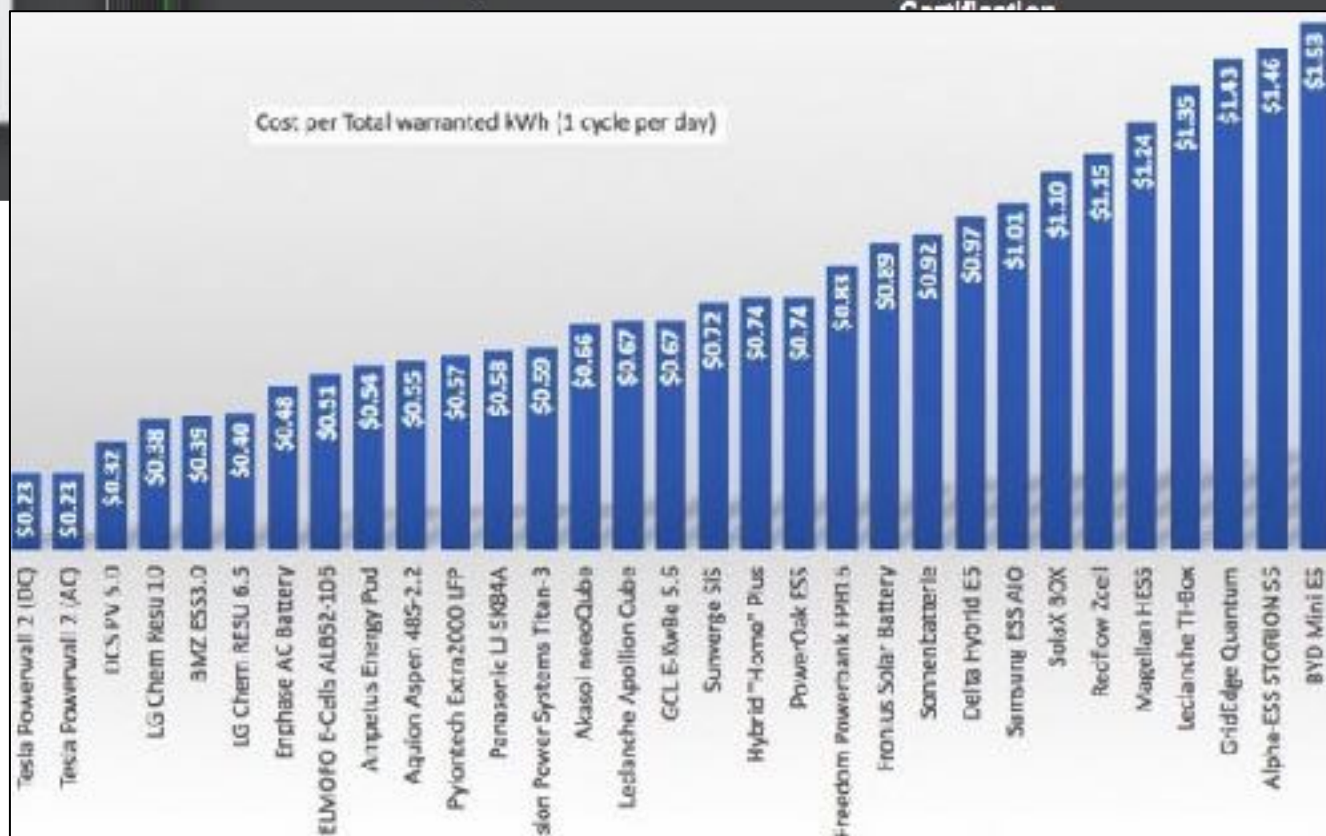
~10Wh smart phone battery

~100Wh laptop battery

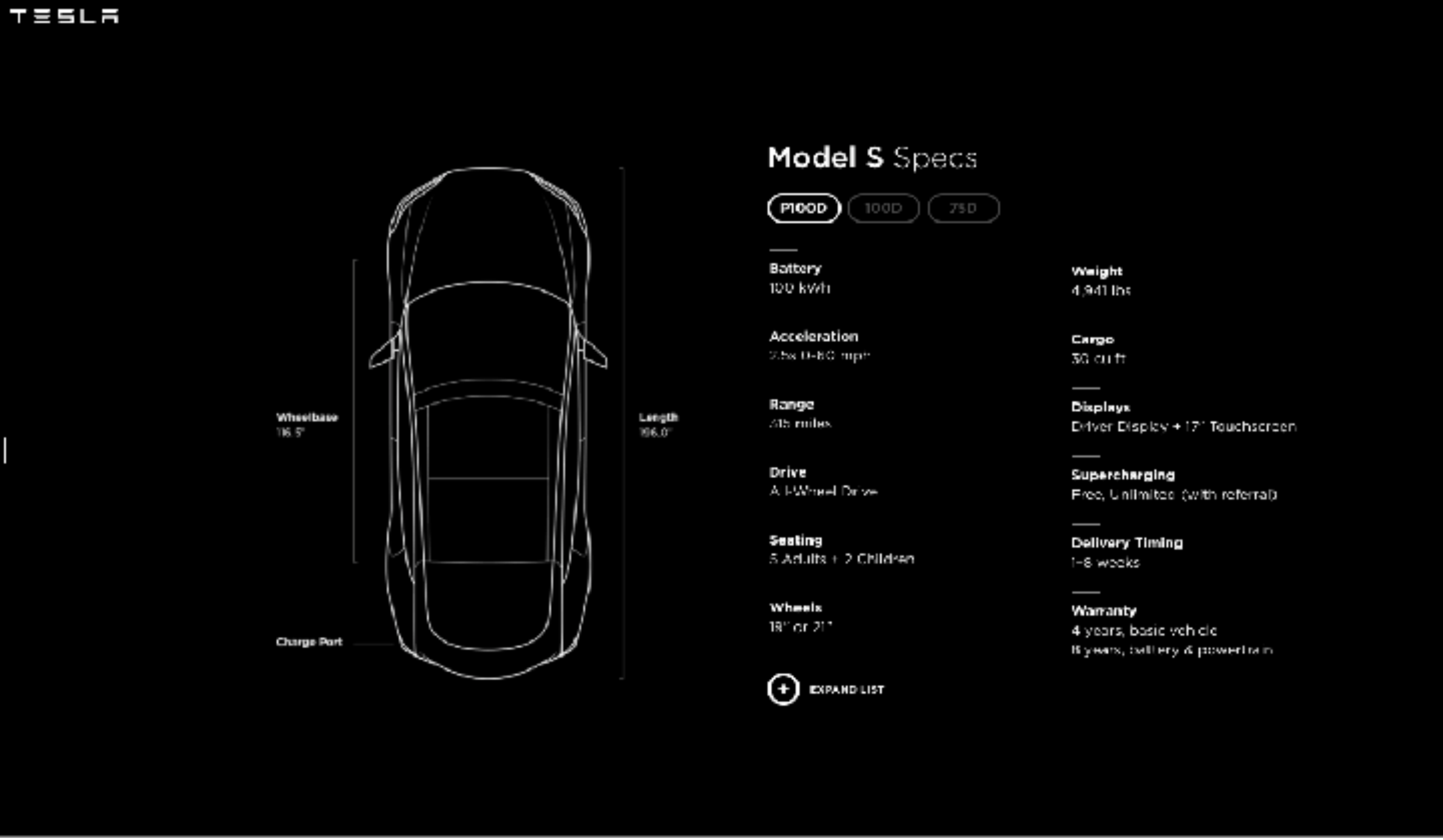


~1kWh portable battery
"generator"





~10kWh home battery


Model S Specs
P100D
100D
75D
Battery
100 kWh
Acceleration
Range
Drive
Seating
Wheels
Weight
4,941 lbs
Cargo
Displays
Supercharging
Free, Unlimited (with referral)
Delivery Timing
Warranty
4 years, basic vehicle
EXPAND LIST
Wheelbase
Length
Charge Port

~100kWh EV

1-10MWh Grid-backup

GTM forecast: 1.6GW in US by 2020

This was built in 2017 in West Caldwell, NJ

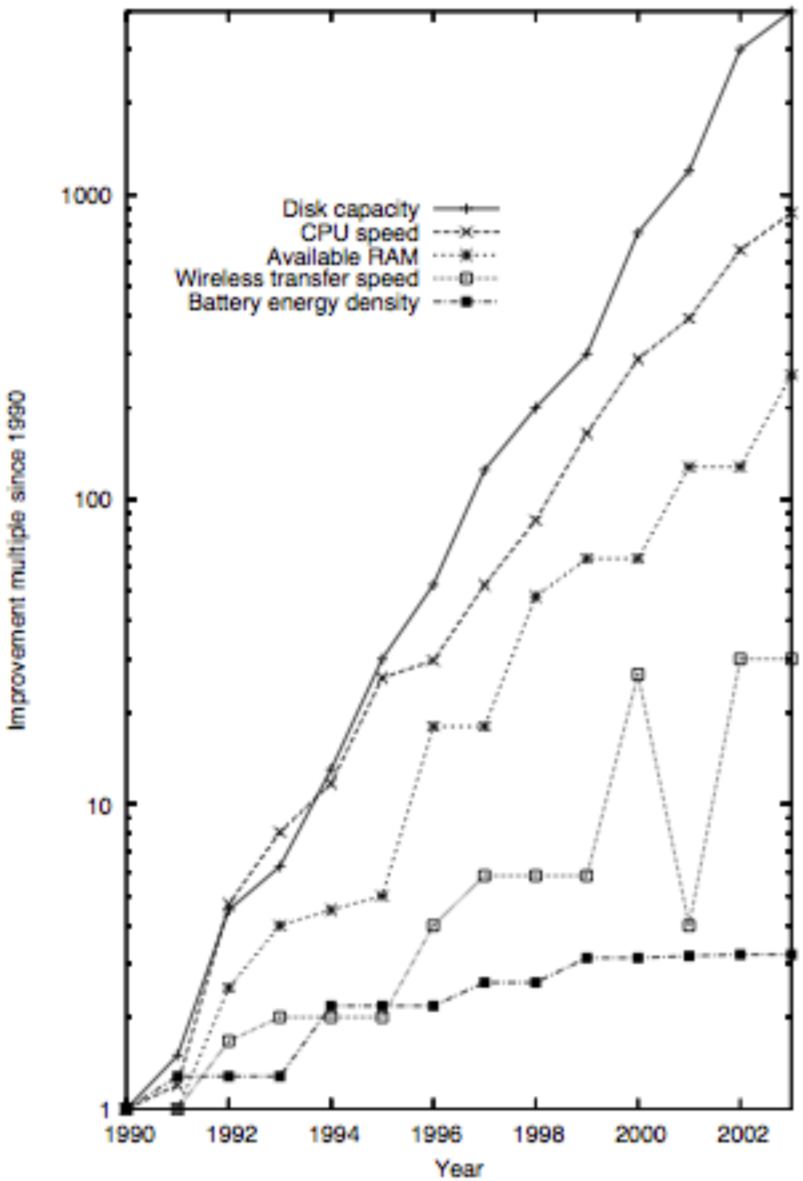
More data: http://css.umich.edu/sites/default/files/U.S._Grid_Energy_Storage_Factsheet_CSS15-17_e2017.pdf

COMPARISON OF LITHIUM CHEMISTRIES

CHARACTERISTIC	LFP ($LiFePO_4$)	NMC ($LiNiMnCoO_2$)	LCO (LiCoO2)	LMO ($LiMn_2O_4$)	LTO ($Li_4Ti_5O_{12}$)
Voltage	3.2VPC (operating range 2.5-3.65VPC)	3.6VPC (operating range 3-4.2VPC)	3.6VPC (operating range 3-4.2VPC)	3.7VPC (operating range 3-4.2VPC)	2.4VPC (operating range 1.8-2.85VPC)
Specific Energy	90-120 Wh/kg	150-220 Wh/kg	150-200 Wh/kg	100-150 Wh/kg	50-80 Wh/kg
Energy Density	333 Wh/l	580 Wh/l	560 Wh/l	420 Wh/l	177 Wh/l
Charge Rate	1C	0.7-1C (>1C shortens life)	0.7-1C (>1C shortens life)	0.7-1C (3C Max)	1C (5C Max)
Charge Voltage	3.5-3.65VPC	4.2VPC	4.2VPC	4.2VPC	2.85VPC
Discharge Rate	1C (30C power cells); 2.0V cut-off	1C (2C on some cells); 2.5V cut-off	1C (>1C shortens life); 2.5V cut-off	1C (>1C shortens life); 2.5V cut-off	10C (30C 5 sec); 1.8V cut-off
Cycle Life (depending on depth of discharge)	2000-4000	1000-2000	500-1000	300-700	3000-7000
Thermal Runaway	270°C (518°F)	210°C (410°F)	150°C (302°F)	250°C (482°F)	NA
Prone to Thermal Runaway	No	Yes	Yes	Yes	No
Applications	Motive power and stationary needing needing high currents and endurance	E-bikes, medical devices, EVs, industrial	Mobile phones, laptops, tablets, cameras	Power Tools, medical devices, electric powertrains	UPS, electric powertrains, solar street lighting
Cost	$	$	$$	$$	$$$

https://relionbattery.com/resource-center/technology/why-choose-lithium https://batteryuniversity.com/

Specifications	Lead Acid	NiCd	NiMH	Li-ion[1]		
				Cobalt	Manganese	Phosphate
Specific energy (Wh/kg)	30–50	45–80	60–120	150–250	100–150	90–120
Internal resistance	Very Low	Very low	Low	Moderate	Low	Very low
Cycle life[2] (80% DoD)	200–300	1,000[3]	300–500[3]	500–1,000	500–1,000	1,000–2,000
Charge time[4]	8–16h	1–2h	2–4h	2–4h	1–2h	1–2h
Overcharge tolerance	High	Moderate	Low	Low. No trickle charge		
Self-discharge/ month (room temp)	5%	20%[5]	30%[5]	<5% Protection circuit consumes 3%/month		
Cell voltage (nominal)	2V	1.2V[6]	1.2V[6]	3.6V[7]	3.7V[7]	3.2–3.3V
Charge cutoff voltage (V/cell)	2.40 Float 2.25	Full charge detection by voltage signature		4.20 typical Some go to higher V		3.60
Discharge cutoff voltage (V/cell, 1C)	1.75V	1.00V		2.50–3.00V		2.50V
Peak load current Best result	5C[8] 0.2C	20C 1C	5C 0.5C	2C <1C	>30C <10C	>30C <10C
Charge temperature	–20 to 50°C (–4 to 122°F)	0 to 45°C (32 to 113°F)		0 to 45°C[9] (32 to 113°F)		
Discharge temperature	–20 to 50°C (–4 to 122°F)	–20 to 65°C (–4 to 149°F)		–20 to 60°C (–4 to 140°F)		
Maintenance requirement	3–6 months[10] (topping chg.)	Full discharge every 90 days when in full use		Maintenance free		
Safety requirements	Thermally stable	Thermally stable, fuse protection		Protection circuit mandatory[11]		
In use since	Late 1800s	1950	1990	1991	1996	1999
Toxicity	Very high	Very high	Low	Low		
Coulombic efficiency[12]	~90%	~70% slow charge ~90% fast charge		99%		
Cost	Low	Moderate		High[13]		



"Don't let anybody tell you batteries are going to get better. They can't, it's physically impossible." Batteries are made of electrons on metal with oxygen in between; without a way to compress matter and make it more dense, battery store can't improve, ever. What people can speak to is "power density" — but on the whole, batteries are "lousy, lousy, lousy, lousy." We use fuels because they have lots of energy. We could use other energy sources, but when push comes to shove, we get a lot of energy out of fuels, because we can put electrons in tiny volumes of space.

Daniel Nocera interviewed in:
http://poptech.org/blog/daniel_nocera_on_personalized_energy