Photo: Solarpraxis AG/Andreas Schlegel

With so many technologies in the market, is there a way to say that one battery technology is better than another?

Spoilt for choice

Battery overview: Batteries are an integral part of the total storage solution offered for renewable energy applications. However in the selection process, comparison of the different batteries available is not easy since chemistries and performance for applications differ. This market overview shows deep cycle batteries that are on the market and the elements that can influence operation and storage.

Batteries are a dime a dozen at the moment. However, good batteries for optimum renewable energy storage are another thing altogether. Selecting the wrong battery can be an expensive mistake. Renewable energy applications require deep cycle batteries, those that can discharge between 50% and 80% of storage capacity repeatedly, enabling maximum capacity and higher cycle counts.

Deep cycle batteries are structurally different compared to others, like starter batteries for cars. Within the deep cycle range, the chemistries vary too. Differentiating one battery type from another can be difficult making it tricky to say which is better.

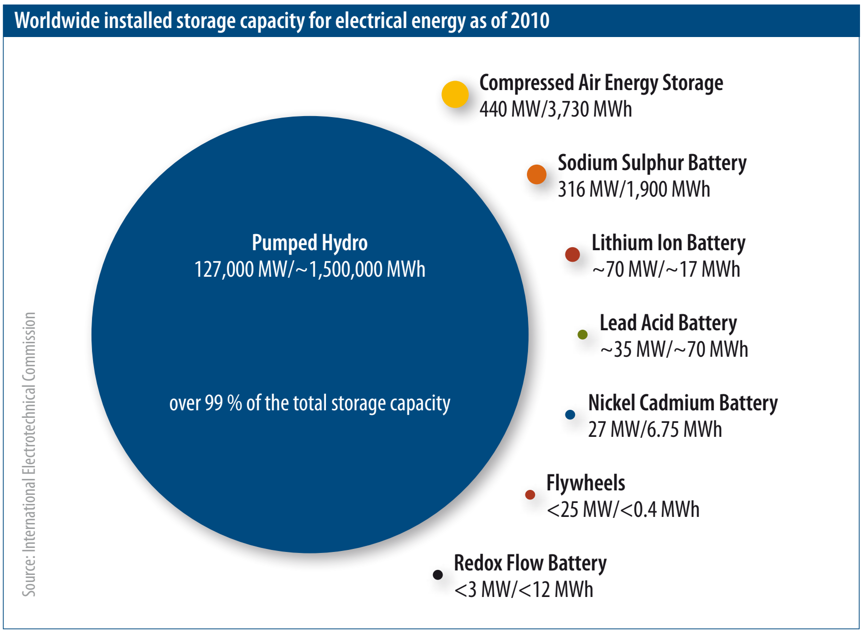
Alfons Westgeest, executive director of the Association of European Automotive and Industrial Battery Manufacturers (Eurobat), says: "I would say there is no clear leader in these battery technologies. Lead-based is competitive in terms of price, installation ease and maintenance. Lithium is more compact. Nickel is somewhere in between lead-based and lithium. And sodium is more for larger scale applications. They all have different characteristics."

With so many technologies on the market is there a way to say that one battery technology is better than another?

How safe is my battery?

Late in 2011, a sodium sulphur battery system made up of 40 battery modules went up in flames at a plant in Joso City in Japan. The battery manufacturer NGK Insulators, Ltd, had to request that cus-

Graphic: Solarpraxis AG/Harald Schütt



Sodium sulphur batteries led the pack as of 2010 but other technologies are catching up.

tomers refrain from using the batteries until the cause was discovered. This affected more than 170 locations in six countries worldwide. In the middle of last year, NGK released their incident report stating that one of the 384 cells in a battery module was faulty and leaked hot molten material causing a short between battery cells in an adjoining block, and thereby causing the whole battery module to catch fire. This fire occurred in a large energy storage application and, luckily, there were no casualties.

The example is not to scare people away from batteries but rather to show that the safety risks ought to be taken seriously. Batteries of all technologies are manufactured according to internationally recognized design, production and quality standards, in order to guarantee their safety for users across all applications.Potential customers must also choose carefully, with the battery selection process demanding know how. .Whoever is installing the battery needs to also know how to handle the different battery types.

A market overview has to therefore cover the different parameters that need to be known. As important as safety questions are, the batteries also differentiate themselves in other factors such as capacity, cycle life, voltages and recommended charge and discharge depths among others.

These parameters are therefore also found in the market overview. Eight companies participated giving details of more than 50 batteries for renewable energy storage.

An important factor in the aspect of safety for lithium-ion (Li-ion) batteries is the material used. Manufacturers like Leclanché indicated in the market overview that ceramic separators in their HS 3200 battery can ensure high thermal and electrical safety. Such separators have the ability to provide a shut down function in situations like a short circuit by cutting current flow. Lead- based batteries, for example, can potentially release flammable hydrogen and oxygen gases during electrolysis. Accumulation of these gases in batteries can be dangerous. In the event of sparks there can potentially be an explosion.

Nevertheless this hazard can be rectified with technology. If the batteries are not valve-regulated, then they need to be placed in a well-ventilated space for safety. Hoppecke offers optional safety measures for its two vented lead-acid batteries: the AquaGen recombiner that can be fitted to all lead acid and Nickel-Cadmium (NiCd) batteries.The hydrogen and oxygen gases that are emitted during electrolysis are fed into the AquaGen recombiner. Such situations can also be prevented with the implementation of battery management systems (BMS). Westgeest says that every battery ought to be integrated with a BMS. Having such a BMS becomes an important safety aspect especially when conditions start getting too hot or too cold for the battery.

In flooded batteries, over charging means the battery will have higher water consumption and would require more maintenance. Trojan Battery's senior applications engineer for the Renewable Energy Group Kalyan Jana adds that if this battery type is over charged over a long time in an uncontrolled-temperature environment, theoretically thermal runaway can happen. "It takes a lot but it can happen. Basically in thermal runaway the battery generates more heat than it can dissipate and it reaches a meltdown," says Jana.

Leclanché's HS 3200, for example, has a ceramic separator in place not only for thermal but also for electrical safety and to improve the battery's abuse tolerance. This also includes an overcharge tolerance.

Saft's product and applications manager Jésus Lugaro explains that, just as with temperature extremes, the BMS will step in when overcharging happens to a Li-ion battery. He explains: "We measure each cell voltage in the modules. This information is sent to the BMS and it has an algorithm to understand if the maximum voltage limit is reached. If so, there is a warning and the current breaker will be activated."

To Eurobat's knowledge, there is no risk of thermal runaway during standard operation of lead-based batteries. Thermal runaway is possible in Li-based batteries because of their more volatile chemistry and higher energy density. However, Li-ion batteries are equipped with sophisticated battery and thermal management systems to keep their operations under safe parameters and protect against this possibility. Therefore they are also safe to operate under standard conditions.

The important point for the buyer is to take note of the user manual and ensure he does not abuse his batteries and then expect them to function over many years.

What temperatures can it stand?

One of the fundamental aspects to look out for in a battery brochure are the operating and storage temperatures. Temperature has an influence on cycle life, an aspect we will cover later. Higher ambient temperatures tend to momentarily improve performance of the battery by lowering internal resistance and increasing the chemical metabolism. However, over a long period of time, this can affect cycle life and increase self-discharge.

At lower temperatures, internal resistance increases and decreases capacity. Temperature compensation is one feature that can help if the battery is exposed to such extremes. That is another reason why we also asked manufacturers why temperature conditions are recommended for their batteries and what kind of regulations are needed.

Trojan Battery product sheets recommend an operating temperature between -20°C and 45°C for their lead-acid batteries. At temperatures below 0°C a state of charge (SOC) greater than 60% is recommended. The SOC is important for lead-acid batteries in cold conditions as in a discharged state, the electrolyte becomes more water-like and freezing temperature increases. At a 40% SOC, the electrolyte can freeze if the temperature reaches approximately -8°C.

Westgeest says that lithium can be a bit more sensitive to temperature extremes, adding: "It's more sensitive to charging and decharging in particular temperature curves." The Fraunhofer Institute for Silicate Research (ISC) adds to this statement saying that even just a few degrees of temperature fluctuations can make a huge difference and this law also applies to Li-ion batteries: adding ten degrees Celsius cuts Li ion battery life in half.

Saft's lithium nickel cobalt aluminum (Li(NCA)) Synerion 24M has operating temperatures between -20°C and 60°C while storage conditions can fall to -30°C and up to 70°C. For Li-ion batteries, the BMS thus becomes the regulator. Saft's Lugaro says that at too high or too low temperatures, the BMS will completely stop the battery at the maximum or minimum operating temperatures and no more current will be able to pass through.

Applications with this battery?

Apart from ensuring the temperatures the batteries are going to be stored and operated at, the buyer also has to think about the application he is going to need the batteries for. Within energy storage, there are power and energy applications, power being the rate at which energy is consumed (in Watts) and energy being the amount of power consumed (in Watt-hours).

Lux Research's Steve Minnihan explains it as an application where "you need continuous energy discharge from anywhere between five minutes and an hour". This application relates to the so-called "big watt" household devices like coffee makers and vacuum cleaners. This calls for a battery that can charge and discharge very quickly. Energy application needs a battery that can provide energy for a longer period of time, meaning longer discharges. Minnihan explains that Li-ion batteries perform well for power applications but fall short when longer discharges are needed.

Saft's Lugaro sees it differently, stressing that it is not that Li-ion batteries are not as good as other technologies with regards to longer discharges. He says:

SOME DEEP CYCLE BATTERY TECHNOLOGIES

Lead based batteries are based on lead dioxide as the active material of the positive electrode, metallic lead in a high surface area porous structure as the negative active material and a sulphuric acid solution. They consist of other sub technologies such as flooded lead acid batteries and valve regulated lead acid (VRLA).

VRLA batteries, also known as sealed batteries, have electrolytes either immobilized by a gel or with the electrolyte immobilized in an absorptive glass mat or AGM.

For VRLA batteries, the use of gel or glass fibers, as in the case of AGM means that they can be installed in any orientation due to the lack of liquids. VRLA batteries are relatively maintenance free but checks like voltage, internal resistance, and capacity verification measurements should be done periodically.

Flooded lead acid batteries have the same internal chemistry but require upright orientation to prevent electrolyte leakage, a ventilated environment to diffuse the gases emitted when cycled and regular maintenance of the electrolyte. Lead based batteries are said to be:

- Relatively efficient but lesser than lithium ion batteries, for example
- With low self discharge rates
- Established with recycle possibilities

However, they have lower energy densities, comparatively.

Lithium ion batteries are based on lithium ions that move back and forth from the cathode to the anode during charge and discharge. The cathode or anode materials can differ in chemistries. The manufacturers who took part in the market overview listed lithium ion based solutions such as lithium iron phosphate (LiFePO4), lithium titanate and lithium nickel cobalt aluminum (Li(NCA)).

The advantages are stated by energy expert Arup Energy Storage's "A five minute guide to electricity storage" as:

- Extremely high energy densities
- Able to tolerate more discharge cycles than other technologies
- High efficiency

Negative effects can be rectified with battery management systems.

Flow batteries use two liquid electrolytes for the opposing charges which act as energy carriers. An ion selective membrane separates the electrolytes and allows selected ions to pass and complete chemical reactions during charging and discharging.

Vanadium redox flow batteries use vanadium ions that are dissolved in the electrolytes in different oxidation states to store energy.

Arup Energy Storage states the advantages of flow batteries as:

- Less sensitive to higher DOD
- Tolerance to a large number of charge/discharge cycles
- Reduced likelihood of cell output being reduced to that of the lowest performing cell
- Virtually unlimited capacity

However, the batteries are said to have low energy densities and are not yet commercially mature.

Nickel based batteries can fall into two categories, mainly: nickel metal hydride (NiMH) and nickel cadmium (NiCd).

NiCd has nickel oxide hydroxide and metallic cadmium as electrodes. NiMh batteries have positive electrodes of nickel oxy hydroxide (NiOOH), like in NiCd, but negative electrodes are a hydrogen absorbing alloy instead of cadmium. Sodium nickel chloride batteries are also used in grid applications.

Molten salt batteries use, as the name suggests, molten salts as an electrolyte. Sodium (Na) and sulphur (S) are the main components. The battery casing acts as the positive electrode while the molten core is the negative electrode. The battery is generally known to operate at high temperatures between 300°C and 350°C, according to Arup Energy Storage.

When the batteries are not in use, they are left under charge, typically, to ensure that they remain molten and ready for use. A reheating process is needed if the battery is allowed to shut down and solidify.

Arup Energy Storage defines the advantages of this battery type as:

- High energy density
- Long life cycle
- Quick response
- Efficient charge/discharge cycles
- Tolerance to high number of charge/discharge cycles.

"Lithium ion performs very well in medium to high power applications compared to other technologies. And with lower power, you still have this characteristic, but the other technologies improve when they use the low current or power. We have an added value in medium high power applications".

Lugaro adds that Saft, for example, uses a model scenario where the client decides which power and energy needs he has and then either the model M, in this case the Synerion 24M, for medium power, or E, the Synerion 48E, for energy will be proposed.

How heavy is it on my pocket?

Price is a very influential factor in the decision-making process for a buyer. When looking solely at capital costs, lead based batteries are seen as relatively cheaper. Lux Research's Steve Minnihan states that on a cell level, lead acid batteries are anywhere between US$100 and US$200 per kWh.

When comparing to the general costs of Li-ion or sodium nickel or even redox flow batteries, it may seem that lead acid batteries have an unbeatable price.

After all Lux Research's baseline scenario for grid-tied systems indicate that by as early as 2022 Li-ion batteries will reach US$506 per kWh storage capacity; sodium nickel chloride batteries, US$473 per kWh; and vanadium redox flow batteries (VRFBs), US$783 per kWh. Does this mean that lead based batteries have a clear advantage in terms of price? Not really.

Minnihan, for example, agrees that the capital cost of lead-acid batteries is low. But he adds: "When you factor in total cost of ownership, replacement, labor and maintenance costs over a five or ten-year time frame, then the newer technologies look substantially better.

"If I want an equivalent amount of energy either from a Li-ion battery or a lead-acid battery, the lead-acid battery is going to be substantially larger and ancillary costs are significantly higher than a lot of analyst firms choose to admit," Minnihan adds.

He is right in pointing this out as capital cost is just one aspect. Delivery costs, site preparation and installation costs all come into play after the purchase of the battery.

When we look at the table, the dimensions and weight of batteries are all different and not very comparable since the capacities largely vary. But a bulkier battery can simply be interpreted with higher transport costs. This is where lead-based batteries may eventually lose out, but the eventually much lower capital cost might cancel this disadvantage out.

If the buyer has a certain budget, then he ought to find out how many cycles the battery can give at a given Depth of Discharge (DOD). DOD is the capacity that the battery has been discharged to as a percentage of maximum capacity.

How long can it run?

The manufacturers in the list provided cycle life for DODs anywhere between 50% and 100%. Cycles for 80% DOD as well as manufacturer's own typical specified DOD was asked for.

It is not exactly a linear relationship but the deeper the DOD, the more capacity you take out and the shorter the cycle life. Deep-cycle batteries are normally not discharged 100%. This would completely empty the battery, something that is not recommended. Manufacturers normally recommend 80% DOD for Li-ion batteries, where 20% of the stored energy remains and 50% DOD for lead-based batteries. This in turn increases the service life of the battery.

Trojan Battery's Kalyan Jana says: "You could have, for example, without any specific reference, a battery that can give 1,000 cycles at 80% DOD but at 50% DOD, 1,200 to 1,300 cycles."

The buyer thus needs to take note of the DOD when looking at cycle life. The cycle life numbers may look extremely impressive, but when the buyer discharges the battery at higher DODs than that indicated, he cannot expect high cycle numbers.

In other words, the real DOD limits the battery capacity. At 80% DOD, only 80% of the battery capacity is free for use. When comparing prices, it then becomes essential to look at the price for the useable battery capacity as opposed to the actual capacity.

How fresh is my battery?

A fresh battery is always better. Not all retail outlets that sell deep-cycle batteries periodically and dutifully recharge them. People tend to forget that batteries can self-discharge when left to sit around. The market overview table shows that up to 5% self-discharge can occur and if a battery is already six months old and has been on the shelf, it might not be at its full capacity. Hence before packing the battery into the shopping cart, check the date of manufacture. ◆

Shamsiah Ali-Oettinger

BATTERY GLOSSARY

Actual battery capacity: According to how control electronics are programmed, the actual battery capacity varies from nominal capacity.

C-rate: The C-rate shows how quickly a battery, with regards to its capacity, is discharged. 1C means the battery discharges completely within an hour. The energy available to be drawn is also dependent on the C-rate.

Calendar life (when battery capacity falls to 80%): The time an inactive battery can be stored before it reaches a critical balance capacity. In our market overview, we have asked for the calendar life of an inactive battery before it reaches 80% of its initial capacity.

Depth of Discharge (DOD): Expressed as %, the battery capacity that has been discharged as a percentage of maximum capacity. A discharge to at least 80% is termed a deep discharge.

Efficiency of battery: Defined by two efficiencies: the coulombic efficiency and the voltage efficiency. The coulombic efficiency of a battery is the ratio of the number of charges that enter the battery during charging compared to the number that can be extracted from the battery during discharging. The voltage efficiency is determined largely by the voltage difference between the charging voltage and voltage of the battery during discharging.

Energy density: A battery with higher energy density will be lighter or smaller than a similar capacity battery with a lower energy density, respectively, whether the density is given as weight (Wh/kg) or volume (Wh/l) density. This factor plays a role in the transportation cost of batteries, where a battery of higher density would be an advantage.

Maximum continuous discharge current: The maximum current at which the battery can be discharged continuously. Usually defined by a manufacturer to prevent excessive discharge rates that can damage the battery or reduce its capacity.

Nominal battery capacity: The amount of electrical charge that can be stored without taking into account it should not be discharged to 100%.

Nominal voltage: The reference voltage of the battery.

Self-discharge (%/month): The amount at which internal chemical reactions reduce the stored charge of the battery without any connection between the electrodes.

State of charge (SOC): Expressed as %, the present battery capacity as a percentage of the maximum capacity.

GENERAL INFORMATION									BATTERY CONTROLLER		DETAILS OF BATTERY UNIT				
Company	Product Name	Manufactured in	Manufacturer	Battery type	Suitable for	Volume: HxBxD (cm)	Weight (kg)	Price (without VAT) in euros	Battery controller included in delivery?	If yes, from own production?	Nominal voltage (V)	Max voltage (at 100% charge) (V)	Voltage at recommended DOD (pls. provide DOD, V)	Maximum continuous discharge current (A)	Nominal battery capacity (kWh)
Akasol GmbH	neeoQube	DE	Akasol GmbH	Li(NMC)*	DE	456x280x456	52	7,500	yes	yes	24/48	29.4/58.8		212/106	5.5
	neeoRack	DE		Li(NMC)*	DE	482x482x266	49	7,150	yes	yes	24/48	29.4/58.8		212/106	5.5
Battery Supplies/ Crown Europe	Crown Solar	US	Crown USA	Open lead acid	ww						6/8/12				
	Solar Tech-nologies	US	Crown USA	Open lead acid	ww						6/8/12				
	Solar Tech-nologies	CN	Battery Supplies	Gel	ww						6/8/12				
	Solar Tech-nologies	CN	Battery Supplies	AGM	ww						6/8/12				
	Solar Technolo-gies (OPzS)	EU	Battery Supplies	Open lead acid	ww						2				
	Solar Tech-nologies (OPzV)	EU	Battery Supplies	Gel	ww						2				
	Solar Tech-nologies (Li ion)	CN	Battery Supplies	LiFePO4	ww				yes	no	Customisable				
	Solar Technolo-gies (semi-traction & monoblock)	EU	Battery Supplies	Open lead acid	ww						6-12				
Cellstrom GmbH	Cellcube	AT	Cellstrom Gmbh	Vanadium Redox Flow	ww	FB Modular: 240.5 x 220 x 465/FB 200-400: 579.2 x 243.8 x 600	Modular max.14T/ 200-400 60T	Modular: 89,000 - 199,000/ 200-400: 849,000			400 V AC(3p) 230/50 hz, 220/60 hz, 120/60 hz, MS 600-36,000			25-500	Modular: 40-130/200-400: 400
Accumulatorenwerke HOPPECKE	OPzS solar. power	DE	Accumulatoren-werke HOPPECKE	Vented lead acid battery in 2 V	ww	420x105x208 - 815x215x580	17.3-229.6		opt.		2	2.08	***	Up to 348.8 A at 10 h discharge for OPzS solar. power 4700 Zelle (C10/10)	0.4-6.8
	OPzS bloc solar.power	DE		Vented lead acid battery in block design 6 V/12 V	ww				opt.		6/12	6.24/12.48	***		1.1-1.7/ 0.6-1.7
	OPzV solar. power	DE		Sealed lead acid battery 2V	ww				opt.		2	2.08-2.14	***		0.4-6
	OPzV bloc solar.power	DE		Sealed lead acid battery in block design 6V/12V	ww				opt.		6/12	6.24-6.42/ 12.48-12.84	***		1.2-1.8/ 0.6-1.8
	solar.bloc	DE		Sealed AGM bat-tery 6V/12V	ww				opt.		6/12	6.24-6.42/ 12.48-12.84	***		1-1.3/ 0.6-1.6
	solar.power pack	DE		24V system of sealed lead acid batteries in block design	EU				yes	yes	24	24.96-25.68	***		7.4
	solar.power system	DE		228-V system of sealed lead acid batteries in block design	EU				yes	yes	228	237.12-243.96	***		11.6
	LiOn	DE		Lithium ion		23x1 x29	12		no		24	29		200	1.3

				LIFETIME			ENERGY DENSITY & POWER		CERTIFICATES AND GUARANTEES					
C-rate with given nominal battery capacity	Actual battery capacity (kWh)	C-rate with given actual battery capacity	Efficiency of battery	Cycle life at 80% DOD and specified C-rate (cycles)	Cycle life at typical specified DOD in % & C-rate (cycles)	Self-discharge (%/month)	Gravimetric energy density (Wh/kg)	Specific power (W/kg)	External safety certificate battery?	If yes, from who?	Other certifications	Other safety features	Comments on battery design	Comments
C/1	4.4	C/1	98%	3,000 (80%; C/1)	3,000 (80%; C/1)	2	105	96	yes					10-year performance guarantee
C/1	4.4	C/1	98%	3,000 (80%; C/1)	3,000 (80%; C/1)	2	112	102	yes					10-year performance guarantee
			80%	1,250 (80%)					yes					For technical data please contact export@batterysupplies.be
			80%	1,250 (80%)					yes					
			75%		600 (75%)				yes					
			75%		600 (75%)				yes					
			80%						yes					
			75%						yes					
			80%	2,000 (80%)					yes					
			80%	600-1,200 (80%)					yes					
C/16 - C/2		C/16 - C/2	65%-80%			< 0.1% per Month	25		yes	TÜV	CE	Non-flammable, not prone to explosion	Vanadium Redox Flow Technology	
C/10	0.2-3.4	C/5	83%			3	23-29.6	200-700	Typetest approval	Norske Veritas	EN 50272-2 EN 60896-11 IEC 61427	- Plastic molded poles - Insulated HOPPECKE system connector technology for max. contact protection - Optional: AquaGen recombiner - Optional: electrolyte circulation pump		
C/10	0.55-0.85/ 0.3-0.85	C/5	83%					200-700			EN 50272-2 EN 60896-11 IEC 61427	- Plastic molded poles - Insulated HOPPECKE system connector technology for max. contact protection - Optional: AquaGen recombiner		
C/10	0.2-3	C/5	83%					200-700			EN 50272-2 EN 60896-21 EN-60896-22 IEC 61427	- Plastic molded poles - Insulated HOPPECKE system connector technology for max. contact protection		
C/10	0.6-0.9/ 0.3-0.9	C/5	83%					200-700						
C/10	0.5-0.65/ 0.3- 0.8	C/5	83%					200-700						
C/10	3.7	C/5	83%					200-700				including battery backup unit		
C/10	5.8	C/5	83%					200-700				integrated BMS and including battery backup unit		
C/1	1.2	C/1	95%				120				UN38.3	incl. BMS, monitoring and logging	Modular system, desired capacity can be done, can be operated as redundant system	

GENERAL INFORMATION									BATTERY CONTROLLER		DETAILS OF BATTERY UNIT				
Company	Product Name	Manufactured in	Manufacturer	Battery type	Suitable for	Volume: HxBxD (cm)	Weight (kg)	Price (without VAT) in euros	Battery controller included in delivery?	If yes, from own production?	Nominal voltage (V)	Max voltage (at 100% charge) (V)	Voltage at recommended DOD (pls. provide DOD, V)	Maximum continuous discharge current (A)	Nominal battery capacity (kWh)
Leclanché SA	HS 3200	DE	Leclanché	Lithium-Titanate	EU	30x75x52	85	8,950			50.6			60	3.2
PROSOL Invest	Sonnenbat-terie			LiFePO4	EU				yes	yes	24-48			100-400	4.6-41
SAFT	Synerion 24M	FR/US	SAFT	Lithium Nickel Cobalt Aluminium	EU, US	13.1x44.8x29.3	18.5		yes	yes	24	28.1	23.1-28.1	160	2
	Synerion 48E	FR/US			EU, US	13.1x44.8x29.3	19		yes	yes	48	48.2	46.2-56.2	50	2.2
Trojan Battery Company	IND9-6V	US	Trojan Battery Company	Flooded lead-acid	EU	610x390x260	100				6	6.36	5.25	500	545 Ah[2]
	IND13-6V	US			EU	610x568x260	143				6	6.36	5.25	500	820 Ah[2]
	IND17-6V	US			EU	610x678x260	188				6	6.36	5.25	500	1090 Ah[2]
	IND23-4V	US			EU	610x568x260	168				4	4.24	3.50	500	1500 Ah[2]
	IND29-4V	US			EU	610x678x260	211				4	4.24	3.50	500	1910 AH[2]
	IND27-2V	US			EU	610x390x260	104				2	2.12	1.75	500	1780 AH[2]
	IND33-2V	US			EU	125x440x260	125				2	2.12	1.75	500	2187 AH[2]
	T105-RE	US			EU	299x264x181	30				6	6.36	5.25	300	250 Ah[2]
	L16RE-A	US			EU	450x295x178	52				6	6.36	5.25	300	360 AH[2]
	L16RE-B	US			EU	450x295x178	54				6	6.36	5.25	300	410 AH[2]
	L16RE-2V	US			EU	450x295x178	54				2	2.12	1.75	300	1235 AH[2]
	J150	US			EU	283x351x181	38				12	12.72	10.50	300	166 AH[2]
	J185P-AC	US			EU	371x281x178	52				12	12.72	10.50	300	226 AH[2]
	J185H-AC	US			EU	371x381x178	58				12	12.72	10.5	300	249 AH[2]
	T-105	US			EU	276x264x181	28				6	6.36	5.25	300	250 Ah[2]
	T-125	US			EU	276x264x181	30				6	6.36	5.25	300	266 Ah[2]
	T-145	US			EU	295x264x181	33				6	6.36	5.25	300	287 AH[2]
	J250P-AC	US			EU	365x295x178	44				6	6.36	5.25	300	278 AH[2]
	J305H-AC	US			EU	365x295x178	45				6	6.36	5.25	300	400 AH[2]
	L16P-AC	US			EU	424x295x178	52				6	6.36	5.25	300	467 AH[2]
	L16H-AC	US			EU	125x295x178	57				6	6.36	5.25	300	483 AH[2]
	24TMX	US			EU	248x286x171	21				12	12.72	10.5	300	94 AH[2]
	27TMX	US			EU	248x324x171	25				12	12.72	10.5	300	117[2]
	27TMH	US			EU	248x324x171	28				12	12.72	10.5	300	128[2]
	30XHS	US			EU	256x355x171	30				12	12.72	10.5	300	144[2]
	U1-AGM	US		VRLA AGM	EU	174x207x132	12				12	12.72	10.5	300	34[2]
	22-AGM	US			EU	205x229x139	18				12	12.72	10.5	300	52[2]
	24-AGM	US			EU	220x274x174	24				12	12.72	10.5	300	84[2]
	27-AGM	US			EU	221x318x174	29				12	12.72	10.5	300	99[2]
	31-AGM	US			EU	233x341x174	31				12	12.72	10.5	300	111[2]
	12-AGM	US			EU	278x345x173	45				12	12.72	10.5	300	
	24-GEL	US		VRLA Gel	EU	236x276x171	24				12	12.72	10.5		85[2]
	27-GEL	US			EU	234x324x171	29				12	12.72	10.5		100[2]
	31-GEL	US			EU	245x329x171	32				12	12.72	10.5		108[2]
	5SHP-GEL	US			EU	283x345x171	39				12	12.72	10.5		137[2]
	8D-GEL	US			EU	233x534x279	71				12	12.72	10.5		265[2]
	6V-GEL	US			EU	276x260x181	31				6	6.36	5.25		198[2]
	TE35-GEL	US			EU	276x244x199	31				6	6.36	5.25		220[2]

** Lithium Nickel Manganese Cobalt | ** Saft battery modules are operational up to 70% output capacity | *** Recommended: 50% DOD/ Voltage depends on the discharge location | depending on the discharge voltage | [1] (under Euro*

				LIFETIME			ENERGY DENSITY & POWER		CERTIFICATES AND GUARANTEES					
C-rate with given nominal battery capacity	Actual battery capacity (kWh)	C-rate with given actual battery capacity	Efficiency of battery	Cycle life at 80% DOD and specified C-rate (cycles)	Cycle life at typical specified DOD in % & C-rate (cycles)	Self-discharge (%/month)	Gravimetric energy density (Wh/kg)	Specific power (W/kg)	External safety certificate battery?	If yes, from who?	Other certifications	Other safety features	Comments on battery design	Comments
C/1	3.2	C/1	> 90%		15,000 (100%; C/1)	< 3	65		yes	TÜV Rheinland	Batso	Ceramic separator		
C/5-0.7C	3.15-29	0.3C-0.9C	95%		5,000 (70%; C/1)	2	100	>100	yes	National Institute, PONY Battery Testing Center	ROHS, CE, SGS, CNAS	Safety ventilation	Anode: Graphite; Cathode: LiFePO4, Dielectric: Membrane	
C/5	2	C/5	95%	6,000 (C/2; 80%)**	6,500 (C/2; 70%)/**	5	104	205	no external at module level, only at system level because Saft commercializes systems		EN50178 IEC60950 IP20 UN3480 IEC62093	SIL2 cell safety UL1642	Current interrupt devices at cells, optimal thermal management, separator material, cell balancing and measurement of V,T,I in the module for module safety	At system level BMS includes over-voltage, over-temperature and current protections
C/5	2.2	C/5	95%	6,000 (C/2; 80%)**	6,500 (C/2; 70%)**	5	115	131			EN50178 IEC60950 IP40 UN3480 EN61000			
	3.27[2]				2,800 (50%)	4	30.58							
	4.92[2]				2,800 (50%)	4	29.07							
	6.54[2]				2,800 (50%)	4	28.75							
	6.00[2]				2,800 (50%)	4	28.0							
	7.64[2]				2,800 (50%)	4	27.62							
	3.56[2]				2,800 (50%)	4	15.85							
	4.37[2]				2,800 (50%)	4	28.60							
	1.50[2]				1,600 (50%)		20.00							
	2.16[2]				1,600 (50%)		24.07							
	2.46[2]				1,600 (50%)		21.95							
	2.47[2]				1,600 (50%)		21.86							
	1.99[2]				1,200 (50%)		19.10							
	2.71[2]				1,200 (50%)		19.19							
	2.99[2]				1,200 (50%)		19.40							
	1.50[2]				1,200 (50%)		18.67							
	1.60[2]				1,200 (50%)		18.75							
	1.72[2]				1,200 (50%)		19.19							
	1.67[2]				1,200 (50%)		26.35							
	2.40[2]				1,200 (50%)		18.75							
	2.80[2]				1,200 (50%)		18.57							
	2.89[2]				1,200 (50%)		19.72							
	1.13[2]				600 (50%)		18.58							
	1.40[2]				600 (50%)		17.86							
	1.54[2]				600 (50%)		18.18							
	1.73[2]				600 (50%)		17.34							
	0.408[2]				1,000 (50%)	3	29.41							
	0.624[2]				1,000 (50%)	3	28.85							
	1.01[2]				1,000 (50%)	3	23.76							
	1.19[2]				1,000 (50%)	3	24.37							
	1.33[2]				1,000 (50%)	3	23.31							
					1,000 (50%)	3								
	1.02[2]				1,000 (50%)	3	23.53							
	1.2[2]				1,000 (50%)	3	24.17							
	1.3[2]				1,000 (50%)	3	24.62							
	1.64[2]				1,000 (50%)	3	23.78							
	3.18[2]				1,000 (50%)	3	22.33							
	1.19[2]				1,000 (50%)	3	26.05							
	1.32[2]				1,000 (50%)	3	23.48							

pean label) | ww = worldwide | opt. = optional | [2] at 100 hrs rate