TECHNOLOGY FACTSHEET

LEAD-ACID (Pb) BATTERY FOR POWER APPLICATIONS

Date of factsheet	29-4-2019
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Sector	Electricity generation
ETS / Non-ETS	Non-ETS
Type of Technology	Storage
Description	Lead-acid batteries store electricity through a reversible chemical reaction. The basic components are a container, electrodes, and an electrolyte. By loading the battery, the electricity is transformed into chemical energy, while during discharge, electrochemical reactions occur at the two electrodes generating a flow of electrons through an external circuit (DNV KEMA, 2013). Lead-acid batteries can be used for a variety of applications such as bulk storage, frequency regulation, peak shaving, and time-of-use management (IRENA, 2017). This factsheet focuses on power applications (<1h discharge time) such as frequency regulation.
TRL level 2020	TRL 9
	Represents the most widely applied technology for electrochemical electricity storage in 2013, with over 130 years of operational experience (DNV-KEMA, 2013).

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	kW		6,500								
			1,000			-			12,000		
			Current			**2030**			**2050**		
Potential	Global	GWe	N/A			-			-		
			-	–	-	Min	–	Max	Min	–	Max
Market share	Global utility scale storage	%	See explanation			-			-		
			-	–	-	Min	–	Max	Min	–	Max

Capacity utlization factor	
Full-load running hours per year	
Unit of Activity	PJ/year
Technical lifetime (years)	3-15 years (IRENA, 2017), 250-2,500 cycles (IRENA, 2017) and potentially even up to 5,000 cycles (May et al., 2017).
Progress ratio	94% (JRC ETRI, 2014)
Hourly profile	No
Explanation	kW is used as functional unit because the amount of power a battery can deliver for short periods of time is more relevant for power applications than the amount of energy that can be stored in the battery. The typical capacity refers to project level capacity, not individual battery capacity. The potential for all battery types is high as there are no significant space or resource constraints, instead demand for storage and costs are usually determining factors when it comes to potential installed capacity. Lead-acid batteries (in total) amounted to 401 MW capacity worldwide in 2015 (0.1% of installed utility-scale storage) - this is both for temporal and short-term storage (IRENA, 2015). Global storage capacity is dominated by pumped hydro storage at 99% of installed capacity (IRENA, 2015). The progress ratio is assumed to be the same as for a generic 7.2 MW sodium-sulfur (NaS) battery (JRC ETRI, 2014).

COSTS

Year of Euro	2015

	Euro per Functional Unit	Current			2030			2050		
Investment costs	€ / kW	392			372			332		
		151	–	473	106	–	402	302	–	402
Other costs per year	€ / kW	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max
Fixed operational costs per year (excl. fuel costs)	€ / kW	5.49			5.21			4.65		
		4.93	–	45.00	4.72	–	6.00	4.23	–	5.63
Variable costs per year	€ / MWh	0.80			0.80			0.80		
		Min	–	Max	Min	–	Max	Min	–	Max

Costs explanation	The sources used have been chosen because they are recent publications and include projections up to (at least) 2030. JRC ETRI (2014) is used as primary source because it distinguishes between short-term applications and temporal storage, and it has the most complete set of data, including CAPEX and FOM/VOM estimates up to 2050. The other sources, FCH JU McKinsey (2014) and Luo et al. (2015), do not make a clear distinction between short-term and temporal storage solutions and do not, or only shortly, elaborate on the cost estimates. Data points for the current (2020) set differ in year per source: 2020 for JRC ETRI (2014), 2013 for FCH JU McKinsey (2015), and 2015 for Luo et al. (2015). FOM costs are calculated using JRC ETRI (2014) assumption that FOM costs are 1.4% of investment costs. It is assumed that FOM costs remain 1.4% of investment costs in 2020, 2030 and 2050. VOM costs are only provided for 2013 by JRC ETRI (2014). It is assumed the VOM costs remain the same in 2020, 2030 and 2050. VOM costs are defined by JRC ETRI as production-related O&M costs that vary with electrical generation. They exclude personnel, fuel, and CO2 costs.

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:* Electricity	PJ	-1.00			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
	Electricity	PJ	1.11			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
		PJ	-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
		PJ	-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max

Energy in- and Outputs explanation	The required amount of electricity input for 1 PJ of electricity output is calculated. A roundtrip efficiency of 90% is assumed based on JRC ETRI (2014).

EMISSIONS (Non-fuel/energy-related emissions or emissions reductions (e.g. CCS)

	Substance	Unit	Current			2030			2050		
Emissions			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
Emissions explanation											

OTHER

Parameter	Unit	Current			2030			2050		
Depth of discharge	%	80			-			-		
		80	–	80	Min	–	Max	Min	–	Max
Charge time	Hours	4.00			-			-		
		2.00	–	6.00	Min	–	Max	Min	–	Max
Discharge time	Hours	0.29			-			-		
		0.25	–	0.33	Min	–	Max	Min	–	Max
Self discharge	% / month	2.00			-			-		
		2.00	–	12.00	Min	–	Max	Min	–	Max

Explanation	JRC ETRI (2014) states that the minimum time necessary to charge a unit is approximately 1 minute. It should be noted that the reference used (DNV-KEMA, 2013) do not specify what is the charge time for short-term applications. Discharge times are estimated based on typical storage capacity to power capacity ratio from JRC ETRI (2014). Also, IEA-ETSAP (2012) states that discharge times for lead-acid batteries can be as low as 10 seconds.

REFERENCES AND SOURCES

DNV-KEMA (2013). Systems Analysis Power to Gas (deliverable 1: Technology review)

IRENA (2017). Electricity Storage Costs

JRC (2014). Energy Technology Reference Indicator (ETRI) projections for 2010-2050

May et. al (2017). Lead batteries for utility energy storage: a review

IRENA (2015). Renewables and Electricity Storage: a technology roadmap for REmap 2030

FCH JU McKinsey (2015). Commercialisation of energy storage in Europe

Luo et al. (2015). Overview of current development in electrical energy storage technologies and the application potential in power system operation

IEA-ETSAP & IRENA (2012). Electricity storage technology brief

Sauer et al. (2007). Detailed cost calculations for stationary battery storage systems. Second International Renewable Energy Storage Conference (IRES II) Bonn, 19.-21.11.2007