TECHNOLOGY FACTSHEET

TNO

Lead-acid Battery for Power Applications

Date of factsheet	19-3-2021
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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 manageme+D12nt (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		6,500.00		
			1,000.00	-	12,000.00

			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	1.00
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, 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	1,221.00			1,156.00			1,025.00		
		1,000.00	–	1,292.00	945.00	–	1,216.00	840.00	–	1,086.00
Other costs per year	€ / kW	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max
Fixed operational costs per year (excl. fuel costs)	€ / kW	17.00			16.00			14.00		
		14.00	–	18.00	13.00	–	17.00	12.00	–	15.00
Variable costs per year	€ /	0.80			0.80			0.80		
		0.80	–	0.80	0.80	–	0.80	0.80	–	0.80

Costs explanation: The reference lead-acid battery project used is a 1-12 MW project with 0.5 hour storage capacity, based on JRC (2014). The investment costs of a lead-acid battery project consist of an energy related part (€/kW) and a storage related part (€/kWh). These two components have been combined into a total investment cost figure for the reference project which is expressed in €/kW. With other power/energy ratio's the investment costs can deviate from the above.

Fixed operational costs are 1.4% of investment costs (JRC, 2014).

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:* Electricity	PJ	-1.00			-			-		
			-1.00	–	-1.00	Min	–	Max	Min	–	Max
	Electricity	PJ	1.11			-			-		
			1.11	–	1.11	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 (2014).

MATERIAL FLOWS (OPTIONAL)

	Material	Unit	Current			2030			2050		
Material flows			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max

Material flows explanation:

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	%	80.00			-			-			
		80.00	–	80.00	*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 (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) does 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 (2014). Also, IEA-ETSAP (2012) states that discharge times for lead-acid batteries can be as low as 10 seconds.										

REFERENCES AND SOURCES

1	DNV-KEMA (2013). Systems Analysis Power to Gas (deliverable 1: Technology review)
2	IRENA (2017). Electricity Storage Costs
3	JRC (2014). Energy Technology Reference Indicator (ETRI) projections for 2010-2050
4	May et. al (2017). Lead batteries for utility energy storage: a review
5	IRENA (2015). Renewables and Electricity Storage: a technology roadmap for REmap 2030
6	IEA-ETSAP & IRENA (2012). Electricity storage technology brief
7	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