TECHNOLOGY FACTSHEET

TNO

Lead-acid (Pb) battery for Large-scale Temporal Electricity Storage

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Sector	Electricity generation
ETS / Non-ETS	Non-ETS
Type of Technology	Storage
Description	Lead-acid (Pb) 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 large-scale solutions (utility-scale or large distributed systems) for storage applications such as time-of-use management (discharge times of >1 hour).
TRL level 2020	TRL 9
	It 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	kWh		365,000.00		
			250,000.00	-	480,000.00

			Current			2030			2050		
Potential	Global	GWh		N/A			-			-	
			-	–	-	Min	–	Max	Min	–	Max
Market share	Global utility scale electricity 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) and also 250-5,000 cycles (IRENA, 2017; May et al., 2017)
Progress ratio	94% (JRC ETRI, 2014)
Hourly profile	No
Explanation	The reference capacity is an indication of the typical size for bulk storage (50-100 MW - discharge times of 4-5 hours) (JRC, 2014). The potential for all battery types is high as there are no significant space or resource constraints, instead the 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) (IRENA, 2015) - this is assumed to be for both temporal and short-term storage. The 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, 2014).

COSTS

Year of Euro	2015

	Euro per Functional Unit	Current			2030			2050		
Investment costs	€ / kWh		243.00			228.00			202.00	
		92.00	–	415.00	44.00	–	360.00	89.00	–	323.00
Other costs per year	€ / kWh		-			-			-	
		Min	–	Max	Min	–	Max	Min	–	Max
Fixed operational costs per year (excl. fuel costs)	€ / kWh		3.40			3.20			2.80	
		1.60	–	5.30	1.50	–	5.00	1.30	–	4.50
Variable costs per year	€ / MWh		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 50-100 MW project with 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 €/kWh. 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		1.18			-			-	
			1.11	–	1.25	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 85% assumed based on JRC (2014) range of 80-90%.

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	4.00			-			-		
		4.00	–	5.00	*Min*	–	*Max*	*Min*	–	*Max*
Self discharge	% / month	2.00			-			-		
		2.00	–	12.00	*Min*	–	*Max*	*Min*	–	*Max*
Explanation	The charge time from DNV KEMA (2013) does not specify if it is for temporal storage applications. JRC (2014) states that the minimum time necessary to charge a unit is approximately 1 minute.									

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 Referency 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 McKinsey (2015) - Commercialisation of energy storage in Europe
7 Luo et al. (2015) - Overview of current development in electrical energy storage technologies and the application potential in power system operation
8 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
9 IEA-ETSAP & IRENA 2012 - Electricity storage technology brief