

2. Technology Catalogue for energy storage

References data sheets

Appendix B

October , 2020



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Technology Roadmap and Mitigation Potential of Utility-scale Electricity Storage in Mexico

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Commissioned by INECC with support of the Mexico-Denmark Program for Energy and Climate Change

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Appendix B. References

Pumped hydro storage

No.	Reference
[1]	IRENA (2017). Electricity storage and renewables: Costs and markets to 2030. Cost of service tool. Retrieved from https://www.irena.org/publications/2017/Oct/Electricity-storage-and-renewables-costs-and-markets
[2]	Gür, T. M. (2018). Review of electrical energy storage technologies, materials and systems: Challenges and prospects for large-scale grid storage. <i>Energy and Environmental Science</i> , 11(10), 2696–2767. https://doi.org/10.1039/c8ee01419a
[3]	Lazard. (2016). <i>Levelized Cost of Storage - Version 2.0</i> . Retrieved from https://www.lazard.com/media/438042/lazard-levelized-cost-of-storage-v20.pdf
[4]	Barbour, E., Wilson, I. A. G., Radcliffe, J., Ding, Y., & Li, Y. (2016). A review of pumped hydro energy storage development in significant international electricity markets. <i>Renewable and Sustainable Energy Reviews</i> , 61, 421–432. https://doi.org/10.1016/j.rser.2016.04.019
[5]	IRENA. (2017). Electricity Storage and Renewables: Cost and Markets to 2030. Retrieved from https://www.irena.org/publications/2017/Oct/Electricity-storage-and-renewables-costs-and-markets
[6]	Luo, X., Wang, J., Dooner, M., & Clarke, J. (2015). Overview of current development in electrical energy storage technologies and the application potential in power system operation. <i>Applied Energy</i> , 137, 511–536. https://doi.org/https://doi.org/10.1016/j.apenergy.2014.09.081
[7]	Schmidt, O., Melchior, S., Hawkes, A., & Staffell, I. (2019). Projecting the Future Levelized Cost of Electricity Storage Technologies. <i>Joule</i> , 3(1), 81–100. https://doi.org/10.1016/j.joule.2018.12.008
[8]	EERA. (2016). Pumped hydro energy storage. Brussels. Retrieved from https://eera-es.eu/wp-content/uploads/2016/03/EERA_Factsheet_Pumped-



	Hydro-Energy-Storage.pdf
[9]	Zakeri, B., & Syri, S. (2015). Electrical energy storage systems: A comparative life cycle cost analysis. <i>Renewable and Sustainable Energy Reviews</i> , 42, 569–596. https://doi.org/10.1016/j.rser.2014.10.011
[10]	Danish Energy Agency. (2019). Technology Data for Energy Storage. Copenhagen, Denmark. Retrieved from https://ens.dk/sites/ens.dk/files/Analyser/technology_data_catalogue_for_energystorage.pdf

Lithium Ion batteries

No.	Reference
[1]	Samsung. (2018). Energy storage system. Yongin. Retrieved from http://www.samsungsdi.com/upload/ess_brochure/201809_SamsungSDI ESS_EN.pdf
[2]	Kokam. (2018). Total energy storage solution provider. Suwon. Retrieved from http://kokam.com/data/2018_Kokam_ESS_Brochure_ver_5.0.pdf
[3]	Kokam. (2017). Superior lithium polymer battery. Suwon. Retrieved from http://kokam.com/data/Kokam_Cell_Brochure_V.4.pdf
[4]	Ads-tec. (2018). StoraXe industrial & infrastructure. Nuertingen. Retrieved from https://www.ads-tec.de/fileadmin/download/doc/brochure/Datasheet_Energy_Industrial_EN.pdf
[5]	Altairnano. (2016). 24 V 70 Ah battery module. Retrieved from https://altairnano.com/products/battery-module/
[6]	Samsung. (2016). Smart battery systems for energy storage. Yongin. Retrieved from http://www.samsungsdi.com/upload/ess_brochure/Samsung SDI brochure_EN.pdf
[7]	Electropedia. (2005). Battery performance characteristics. Retrieved from https://www.mpoweruk.com/performance.htm



No.	Reference
[8]	Fathima, A. H., & Palanisamy, K. (2018). Renewable systems and energy storages for hybrid systems. Hybrid-renewable energy systems in microgrids: Integration, developments and control. https://doi.org/10.1016/B978-0-08-102493-5.00008-X
[9]	Lazard. (2017). Levelized cost of storage 2017. Retrieved from https://www.lazard.com/perspective/levelized-cost-of-storage-2017/
[10]	LG. (2018). Advanced batteries for energy storage. Seoul. Retrieved from http://www.lgchem.com/upload/file/product/LGChem_Catalog_Global_2018.pdf
[11]	Tesla. (2016). Addressing peak energy demand with the Tesla Powerpack. Retrieved from https://www.tesla.com/da_DK/blog/addressing-peak-energy-demand-tesla-powerpack?redirect=no
[12]	Tesla. (2017). Tesla Powerpack to enable large scale sustainable energy to South Australia. Retrieved from https://www.tesla.com/da_DK/blog/Tesla-powerpack-enable-large-scale-sustainable-energy-south-australia?redirect=no Page
[13]	ESA. (2018). Frequency regulation services and a firm wind product: AES energy storage laurel mountain battery energy storage system. Retrieved from https://energystorage.org/project-profile/frequency-regulation-services-and-a-firm-wind-product-aes-energy-storage-laurel-mountain-battery-energy-storage-bess/
[14]	Bloomberg New Energy Finance. (2018). New Energy Outlook 2018. Retrieved from https://bnef.turtl.co/story/neo2018.pdf?autoprint=true&teaser=true
[15]	IRENA. (2015). Battery Storage for Renewables: Market status and technology outlook. Abu Dhabi. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_Battery_Storage_report_2015.pdf
[16]	IRENA (2017). Electricity storage and renewables: Costs and markets to 2030. Cost of service tool. Retrieved from https://www.irena.org/publications/2017/Oct/Electricity-storage-and-renewables-costs-and-markets



No.	Reference
[17]	DTI. (2017). Smart grid ready Battery Energy Storage System for future grid. Aarhus. Retrieved from https://www.energiforskning.dk/sites/energiteknologi.dk/files/slutrappporter/bess_final_report_forskel_10731.pdf
[18]	Chen, H., Cong, T. N., Yang, W., Tan, C., Li, Y., & Ding, Y. (2009). Progress in electrical energy storage system: A critical review. <i>Progress in Natural Science</i> , 19(3), 291–312. https://doi.org/10.1016/j.pnsc.2008.07.014
[19]	Greenwood, D. M., Lim, K. Y., Patsios, C., Lyons, P. F., Lim, Y. S., & Taylor, P. C. (2017). Frequency response services designed for energy storage. <i>Applied Energy</i> , 203, 115–127. https://doi.org/10.1016/j.apenergy.2017.06.046
[20]	Benato, R., Bruno, G., Palone, F., Polito, R. M., & Rebolini, M. (2017). Large-scale electrochemical energy storage in high voltage grids: Overview of the Italian experience. <i>Energies</i> , 10(1). https://doi.org/10.3390/en10010108
[21]	Zakeri, B., & Syri, S. (2015). Electrical energy storage systems: A comparative life cycle cost analysis. <i>Renewable and Sustainable Energy Reviews</i> , 42, 569–596. https://doi.org/10.1016/j.rser.2014.10.011
[22]	Akhil, A. A., Huff, G., Currier, A. B., Hernandez, J., Bender, D. A., Kaun, B. C., ... Schoenung, S. (2016). DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA. Sandia National Laboratories, (January), 347. https://doi.org/10.2172/1431469
[23]	Danish Energy Agency. (2019). Technology Data for Energy Storage. Copenhagen, Denmark. Retrieved from https://ens.dk/sites/ens.dk/files/Analyser/technology_data_catalogue_for_energy_storage.pdf



Lead-acid batteries

No.	Reference
[1]	IRENA (2017). Electricity storage and renewables: Costs and markets to 2030. Cost of service tool. Retrieved from https://www.irena.org/publications/2017/Oct/Electricity-storage-and-renewables-costs-and-markets
[2]	Luo, X., Wang, J., Dooner, M., & Clarke, J. (2015). Overview of current development in electrical energy storage technologies and the application potential in power system operation. <i>Applied Energy</i> , 137, 511–536. https://doi.org/https://doi.org/10.1016/j.apenergy.2014.09.081
[3]	Schmidt, O., Melchior, S., Hawkes, A., & Staffell, I. (2019). Projecting the Future Levelized Cost of Electricity Storage Technologies. <i>Joule</i> , 3(1), 81–100. https://doi.org/10.1016/j.joule.2018.12.008
[4]	May, G. J., Davidson, A., & Monahov, B. (2018). Lead batteries for utility energy storage: A review. <i>Journal of Energy Storage</i> , 15, 145–157. https://doi.org/10.1016/j.est.2017.11.008
[5]	Zakeri, B., & Syri, S. (2015). Electrical energy storage systems: A comparative life cycle cost analysis. <i>Renewable and Sustainable Energy Reviews</i> , 42, 569–596. https://doi.org/10.1016/j.rser.2014.10.011
[6]	Kairies, K.-P. (2017). Battery storage technology improvements and cost reductions to 2030: A deep dive. Düsseldorf. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Events/2017/Mar/15/2017_Kairies_Battery_Cost_and_Performance_01.pdf
[7]	Lazard. (2016). Levelized Cost of Storage - Version 2.0. Retrieved from https://www.lazard.com/media/438042/lazard-levelized-cost-of-storage-v20.pdf
[8]	Fullriver. (2018). DC400-6. Retrieved from https://www.fullriverbattery.com/product/dc400-6/
[9]	EASE/EERA. (2013). European Energy Storage Technology Development Roadmap Toward 2030. Retrieved from https://www.eera-set.eu/wp-content/uploads/148885-EASE-recommendations-Roadmap-04.pdf



Sodium-sulfur batteries

No.	Reference
[1]	IRENA (2017). Electricity storage and renewables: Costs and markets to 2030. Cost of service tool. Retrieved from https://www.irena.org/publications/2017/Oct/Electricity-storage-and-renewables-costs-and-markets
[2]	Danish Energy Agency. (2019). Technogy Data for Energy Storage. Copenhagen, Denmark. Retrieved from https://ens.dk/sites/ens.dk/files/Analyser/technology_data_catalogue_for_energystorage.pdf
[3]	Subburaj, A. S., Pushpakaran, B. N., & Bayne, S. B. (2015). Overview of grid connected renewable energy-based battery projects in USA. <i>Renewable and Sustainable Energy Reviews</i> , 45, 219–234. https://doi.org/https://doi.org/10.1016/j.rser.2015.01.052
[4]	Kairies, K.-P. (2017). Battery storage technology improvements and cost reductions to 2030: A deep dive. Düsseldorf. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Events/2017/Mar/15/2017_Kairies_Battery_Cost_and_Performance_01.pdf
[5]	Diaz-Gonzalez, F., Sumper, A., & Gomis-Bellmunt, O. (2016). Energy Storage Technologies. In <i>Energy Storage in Power Systems</i> (pp. 93–141). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118971291.ch4
[6]	Schmidt, O., Melchior, S., Hawkes, A., & Staffell, I. (2019). Projecting the Future Levelized Cost of Electricity Storage Technologies. <i>Joule</i> , 3(1), 81–100. https://doi.org/10.1016/j.joule.2018.12.008
[7]	Zakeri, B., & Syri, S. (2015). Electrical energy storage systems: A comparative life cycle cost analysis. <i>Renewable and Sustainable Energy Reviews</i> , 42, 569–596. https://doi.org/10.1016/j.rser.2014.10.011



Vanadium redox flow batteries

No.	Reference
[1]	IRENA (2017). Electricity storage and renewables: Costs and markets to 2030. Cost of service tool. Retrieved from https://www.irena.org/publications/2017/Oct/Electricity-storage-and-renewables-costs-and-markets
[2]	Danish Energy Agency. (2019). Technogy Data for Energy Storage. Copenhagen, Denmark. Retrieved from https://ens.dk/sites/ens.dk/files/Analyser/technology_data_catalogue_for_energystorage.pdf
[3]	Luo, X., Wang, J., Dooner, M., & Clarke, J. (2015). Overview of current development in electrical energy storage technologies and the application potential in power system operation. <i>Applied Energy</i> , 137, 511–536. https://doi.org/https://doi.org/10.1016/j.apenergy.2014.09.081
[4]	IRENA (2017). Electricity storage and renewables: Costs and markets to 2030. Retrieved from https://www.irena.org/publications/2017/Oct/Electricity-storage-and-renewables-costs-and-markets
[5]	Lai, C. S., Jia, Y., Lai, L. L., Xu, Z., McCulloch, M. D., & Wong, K. P. (2017). A comprehensive review on large-scale photovoltaic system with applications of electrical energy storage. <i>Renewable and Sustainable Energy Reviews</i> , 78, 439–451
[6]	Schmidt, O., Melchior, S., Hawkes, A., & Staffell, I. (2019). Projecting the Future Levelized Cost of Electricity Storage Technologies. <i>Joule</i> , 3(1), 81–100. https://doi.org/10.1016/j.joule.2018.12.008
[7]	EASE/EERA. (2013). European Energy Storage Technology Development Roadmap Toward 2030. Retrieved from https://www.eera-set.eu/wp-content/uploads/148885-EASE-recommendations-Roadmap-04.pdf
[8]	Zakeri, B., & Syri, S. (2015). Electrical energy storage systems: A comparative life cycle cost analysis. <i>Renewable and Sustainable Energy Reviews</i> , 42, 569–596. https://doi.org/10.1016/j.rser.2014.10.011



Molten salt

No.	Reference
[1]	Fedato E., Baldini M., Dalla Riva A., Mora Alvarez D.F., Wiuff A.K., Hethey J., Cerrajero E., Estebaranz J.M., (2019). Feasibility analysis of GRIDSOL technology in Fuerte Ventura: A case study. J. Eng., 2019, Vol. 2019 Iss. 18, pp. 5208-5213
[2]	Epp, B. (2018). Molten salt storage 33 times cheaper than lithium-ion batteries. Retrieved November 26, 2019, from https://www.solarthermalworld.org/news/molten-salt-storage-33-times-cheaper-lithium-ion-batteries
[3]	Data obtained from consultation with analysts of the Gridsol project through the Danish Energy Agency
[4]	Trabelsi, S. E., Chargui, R., Qoaider, L., Liqreina, A., & Guizani, A. (2016). Techno-economic performance of concentrating solar power plants under the climatic conditions of the southern region of Tunisia. Energy Conversion and Management, 119, 203–214. https://doi.org/10.1016/j.enconman.2016.04.033
[5]	Danish Energy Agency. (2019). Technology Data for Energy Storage. Copenhagen, Denmark. Retrieved from https://ens.dk/sites/ens.dk/files/Analyser/technology_data_catalogue_for_energy_storage.pdf



Compressed air energy storage

No.	Reference
[1]	IRENA (2017). Electricity storage and renewables: Costs and markets to 2030. Cost of service tool. Retrieved from https://www.irena.org/publications/2017/Oct/Electricity-storage-and-renewables-costs-and-markets
[2]	Huang, Y., Keatley, P., Chen, H. S., Zhang, X. J., Rolfe, A., & Hewitt, N. J. (2018). Techno-economic study of compressed air energy storage systems for the grid integration of wind power. <i>International Journal of Energy Research</i> , 42(2), 559–569. https://doi.org/10.1002/er.3840
[3]	Danish Energy Agency. (2019). Technology Data for Energy Storage. Copenhagen, Denmark. Retrieved from https://ens.dk/sites/ens.dk/files/Analyser/technology_data_catalogue_for_energy_storage.pdf
[4]	Kaldemeyer, C., Boysen, C., & Tuschy, I. (2016). Compressed Air Energy Storage in the German Energy System – Status Quo & Perspectives. <i>Energy Procedia</i> , 99, 298–313. https://doi.org/10.1016/j.egypro.2016.10.120
[5]	Komarnicky, P., Lombardi, P., Styczynski, Z. (2017). <i>Electric Energy Storage systems</i> . Springer-Verlag GmbH Germany
[6]	Schmidt, O., Melchior, S., Hawkes, A., & Staffell, I. (2019). Projecting the Future Levelized Cost of Electricity Storage Technologies. <i>Joule</i> , 3(1), 81–100. https://doi.org/10.1016/j.joule.2018.12.008
[7]	Gustavsson, J. (2016). <i>Energy Storage Technology Comparison</i> . KTH Industrial Engineering and Management. Retrieved from http://www.diva-portal.org/smash/get/diva2:953046/FULLTEXT01.pdf
[8]	Diaz-Gonzalez, F., Sumper, A., & Gomis-Bellmunt, O. (2016). Energy Storage Technologies. In <i>Energy Storage in Power Systems</i> (pp. 93–141). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118971291.ch4
[9]	Kairies, K.-P. (2017). Battery storage technology improvements and cost reductions to 2030: A deep dive. Düsseldorf. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Events/2017/Mar/15/2017_Kairies_Battery_Cost_and_Performance_01.pdf



[10]	EASE/EERA. (2013). European Energy Storage Technology Development Roadmap Toward 2030. Retrieved from https://www.eera-set.eu/wp-content/uploads/148885-EASE-recommendations-Roadmap-04.pdf
[11]	Zakeri, B., & Syri, S. (2015). Electrical energy storage systems: A comparative life cycle cost analysis. <i>Renewable and Sustainable Energy Reviews</i> , 42, 569–596. https://doi.org/10.1016/j.rser.2014.10.011

Flywheel

No.	Reference
[1]	IRENA (2017). Electricity storage and renewables: Costs and markets to 2030. Cost of service tool. Retrieved from https://www.irena.org/publications/2017/Oct/Electricity-storage-and-renewables-costs-and-markets
[2]	Danish Energy Agency. (2019). Technology Data for Energy Storage. Copenhagen, Denmark. Retrieved from https://ens.dk/sites/ens.dk/files/Analyser/technology_data_catalogue_for_energy_storage.pdf
[3]	Luo, X., Wang, J., Dooner, M., & Clarke, J. (2015). Overview of current development in electrical energy storage technologies and the application potential in power system operation. <i>Applied Energy</i> , 137, 511–536. https://doi.org/10.1016/j.apenergy.2014.09.081
[4]	IRENA (2017). Electricity storage and renewables: Costs and markets to 2030. Retrieved from https://www.irena.org/publications/2017/Oct/Electricity-storage-and-renewables-costs-and-markets
[5]	Schmidt, O., Melchior, S., Hawkes, A., & Staffell, I. (2019). Projecting the Future Levelized Cost of Electricity Storage Technologies. <i>Joule</i> , 3(1), 81–100. https://doi.org/10.1016/j.joule.2018.12.008
[6]	Zakeri, B., & Syri, S. (2015). Electrical energy storage systems: A comparative life cycle cost analysis. <i>Renewable and Sustainable Energy Reviews</i> , 42, 569–596. https://doi.org/10.1016/j.rser.2014.10.011