

Electric storage

# Electrical Energy Storage technologies

<http://grid.coop/storage.pdf>

Daily storage

Seasonal storage

Storage Technology	Mass Energy Density, MWH/tonne		Volume Energy Density, MWH/m <sup>3</sup>		Cost, \$1000/MW (equipment)		Cost, \$1000/MWH (storage)		Self Discharge (% per month)		Round Trip Efficiency		Lifetime (cycles)		Lifetime (years)		Cost, 100MW nameplate, 1GWH storage (10 hours), millions of dollars		Cost, 100MW nameplate, 100GWH storage (1000 hours), millions of dollars	
	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
NH3 synthesis/combustion[1]	5.18	6.25	3.53	4.26	600	1600	0.07	0.25	0%	1%	20%	50%			10	30	\$60	\$160	\$67	\$185
LH2 syn/comb. [2]	33.39	39.49	2.37	2.8	600	1000	0.5	2	5%	75%	30%	50%			10	30	\$61	\$102	\$110	\$300
H2 (compressed gas storage)	33.39	39.49			500	800	10	50	0%	5%	35%	75%					\$60	\$130	\$1,050	\$5,080
CAES (compressed air) [3]			0.002		400	500	1	5	0%	1%	80%	85%			30		\$41	\$55	\$140	\$550
Thermal [4]	0.020	0.10	0.020	0.100	250	500	10	45	40%	75%	90%	95%					\$35	\$95	\$1,025	\$4,550
Pumped Hydro (100m) [5]			0.0003		400	500	10	45	0%		75%				30		\$50	\$95	\$1,040	\$4,550
Xtreme Power (dry cell) [13]							400	500									\$400	\$500	\$40,000	\$50,000
Vanadium Flow Battery [12]	0.0250	0.04	0.004	0.011	2750	3750	100	200	1%	10%	70%	80%	10000	13000	10	20	\$375	\$575	\$10,275	\$20,375
Flywheel [6]	2.0E-4	0.20					300		N/A	N/A	80%	90%			10	20	\$300		\$30,000	
NiMH Battery [7]	0.030	0.08	0.0003				364		30%		66%		500	1000	3	5	\$364		\$36,400	
NiCad Battery[8]	0.040	0.06	0.0001				400		20%		70%	90%		1500	3	5	\$400		\$40,000	
Lithium Ion Battery [9]	0.160	0.20	0.0002				300		5%		99%			1200	3	5	\$300		\$30,000	
Lithium Polymer Battery [10]	0.130	0.20					500		10%		99%			1000	3	5	\$500		\$50,000	
Lead Acid Battery [11]	0.030	0.04	0.0001				100	200	10%		70%	92%	500	800	3	5	\$100	\$200	\$10,000	\$20,000

Notes

Costs are broken into cost per MW nameplate (input) capacity, and per MWH incremental storage cost

- [1] Ammonia Synthesis using Freedom Fertilizer 100-150MW nameplate wind to NH3 plant (water electrolysis, cryo air separation, haber-bosch reactor and storage). Round trip efficiencies are assuming a low of 20% for conversion of a diesel engine to NH3, and a potential for 50% for direct ammonia fuel cells. Volume and Mass energy are calculated from HHV (high heating value) and LHV (low heating value) of Ammonia and Hydrogen, from [hydrogen.pnl.gov/cocoon/morf/projects/hydrogen/datasheets/lower\\_and\\_higher\\_heating\\_values.xls](http://hydrogen.pnl.gov/cocoon/morf/projects/hydrogen/datasheets/lower_and_higher_heating_values.xls)
- [2] Liquid hydrogen has boil-off issues, and energy to liquify is significant. Compressed hydrogen also has significant energy and cost requirements. Round trip H2 efficiencies are probably overly generous.
- [3],[5] Equipment cost is a ballpark educated guess
- [4] Thermal storage, such as electrical heating water for later use, or a solar thermal plant. Assumes storage as thermal. Cannot put electricity in, and get electricity back out at the 90-95% round trip ranges. (Thermal-in electrical out, or electrical in thermal out is 90-95% round trip)
- [6] Flywheels are efficient, but tends toward very short duration loads
- [7-11] Various battery technologies have maximum 3-5 year lifetime with daily cycling
- [12] 6M EU, \$7.5M USD for 2MW system, [http://www.seai.ie/Publications/Renewables\\_Publications/VRB-ESS-Energy-Storage-Rpt-Final.pdf](http://www.seai.ie/Publications/Renewables_Publications/VRB-ESS-Energy-Storage-Rpt-Final.pdf)  
No obvious breakdown of equipment vs storage for VRB batteries are available, est. from [http://thefraserdomain.typepad.com/energy/2006/01/vandium\\_reflux\\_.html](http://thefraserdomain.typepad.com/energy/2006/01/vandium_reflux_.html)  
Density guessed from [http://www.pdenery.com/en/technology/energy\\_storage\\_systems/technical\\_specifications/technical\\_specifications.html](http://www.pdenery.com/en/technology/energy_storage_systems/technical_specifications/technical_specifications.html)
- [13] Target of \$500/KWH .. <http://gigaom.com/cleantech/xtreme-power-raising-funds-for-extreme-plans/>

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