Imperial College London

Revenues and potential profitability of electricity storage

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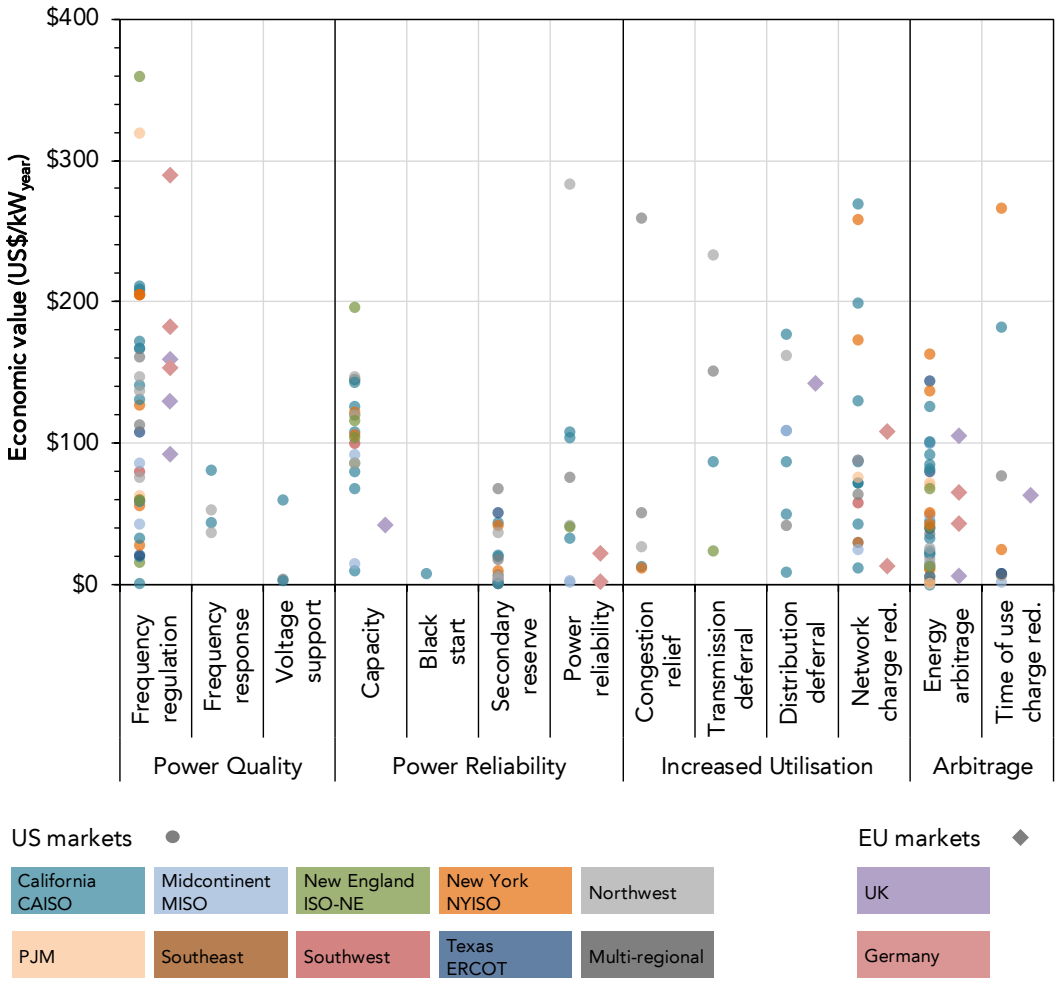
Grantham Institute

Wide spread of revenue potential for electricity storage in common applications

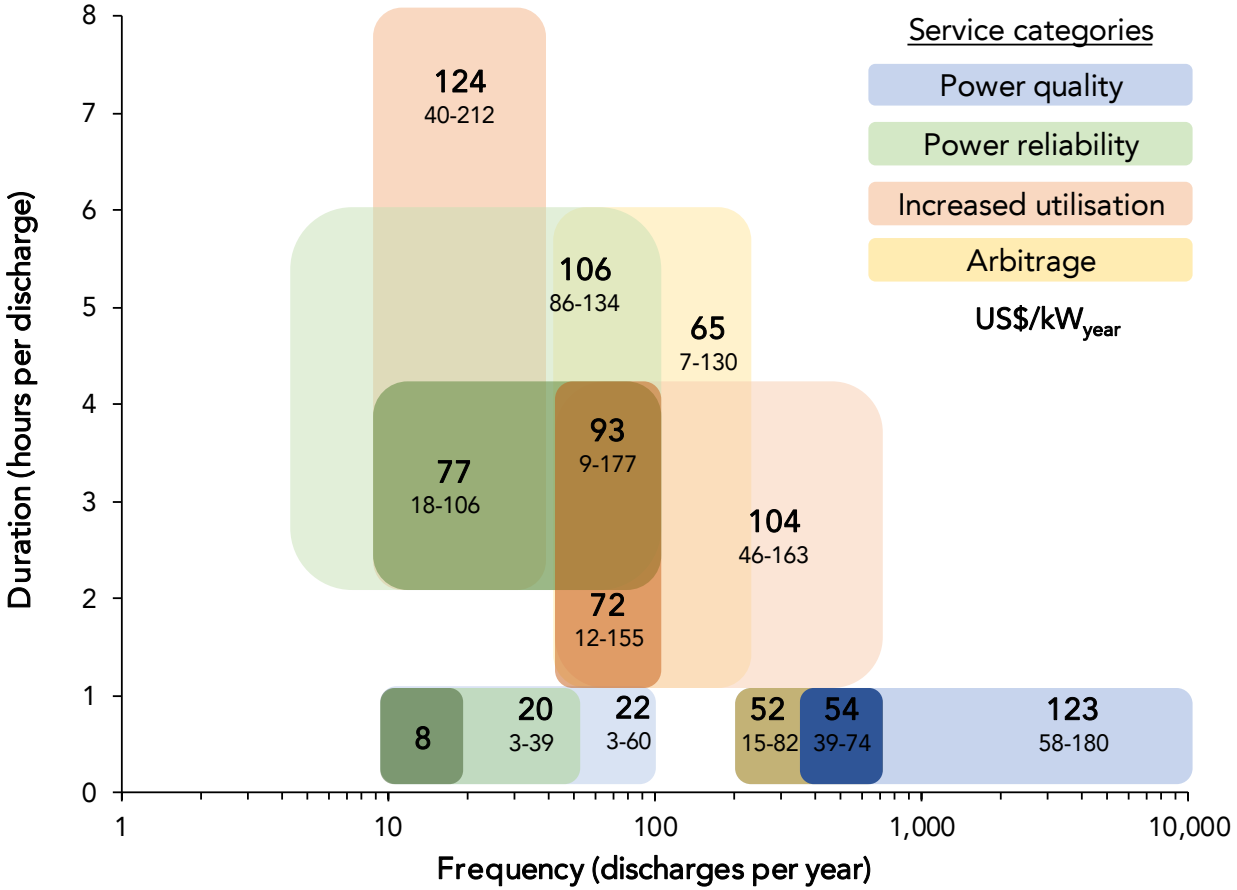
Data Review



Source: Graph structure and data for US from Balducci et al. Assigning value to energy storage systems. Energy Environ. Sci. 11, 1926–1944 (2018).

Revenue potential varies with application requirements

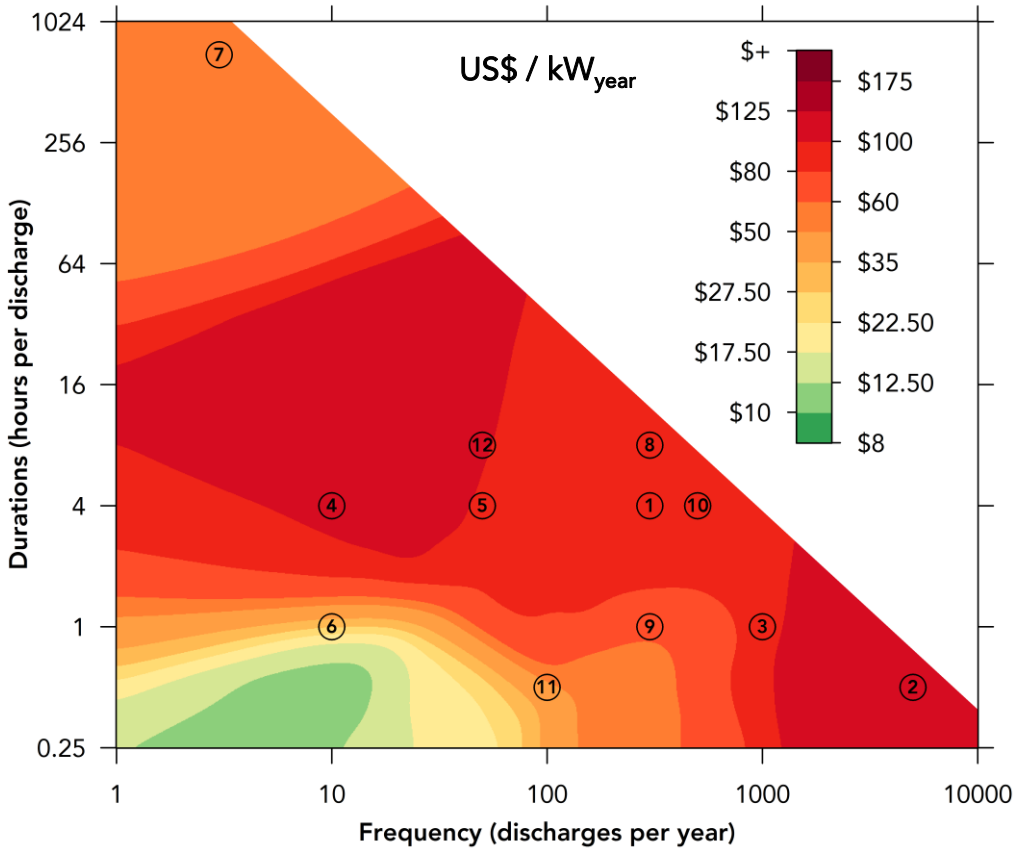
Revenue vs requirements



Source: Application requirements from Akhil, A. et al. DOE/EPRI 2015 electricity storage handbook in collaboration with NRECA. (Sandia National Laboratories, 2015).
Service categories from Battke, B. & Schmidt, T. S. Cost-efficient demand-pull policies for multi-purpose technologies. Appl. Energy 155, 334–348 (2015).

Reward for power capacity increases with frequency and discharge duration

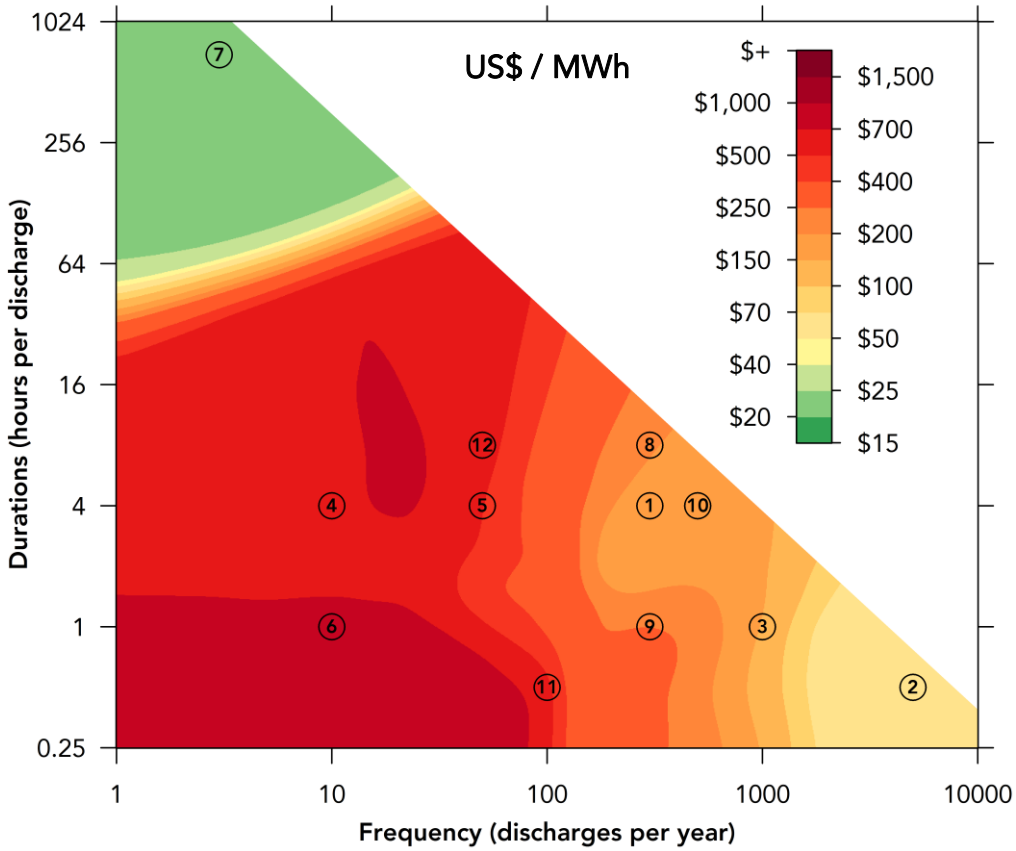
Revenue potential – power capacity



Note: Circled numbers refer to 12 core applications defined in Schmidt, O., Melchior, S., Hawkes, A. & Staffell, I. Projecting the Future Levelized Cost of Electricity Storage Technologies. Joule 3, 1–20 (2019).

Reward for discharged energy increases with reducing cycle frequency

Revenue potential – discharged energy



Note: Circled numbers refer to 12 core applications defined in Schmidt, O., Melchior, S., Hawkes, A. & Staffell, I. Projecting the Future Levelized Cost of Electricity Storage Technologies. Joule 3, 1–20 (2019).

Recap: Lifetime cost for 9 technologies in various applications up to 2050

Levelised cost of storage (LCOS) & Annuitised capacity cost (ACC)

$$LCOS\left[\frac{\$}{MWh}\right] = \frac{Investment\ cost\ +\ Operating\ cost\ +\ Disposal\ cost}{Electricity\ discharged}$$

$$ACC\left[\frac{\$}{kW_{year}}\right] = \frac{Investment\ cost\ +\ Operating\ cost\ +\ Disposal\ cost}{Power\ capacity}$$

- Discounted cost of a MWh discharged or for providing a kW power per year.

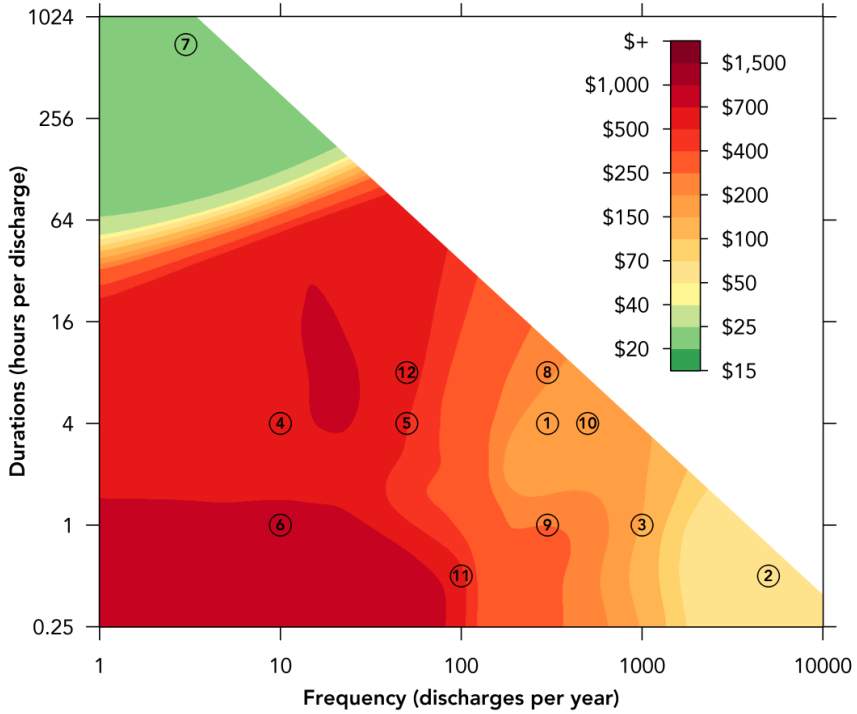
Source: Schmidt, O., Melchior, S., Hawkes, A. & Staffell, I. Projecting the Future Levelized Cost of Electricity Storage Technologies. Joule 3, 1–20 (2019).

Comparing revenue potential (energy) and levelised cost of storage suggests…

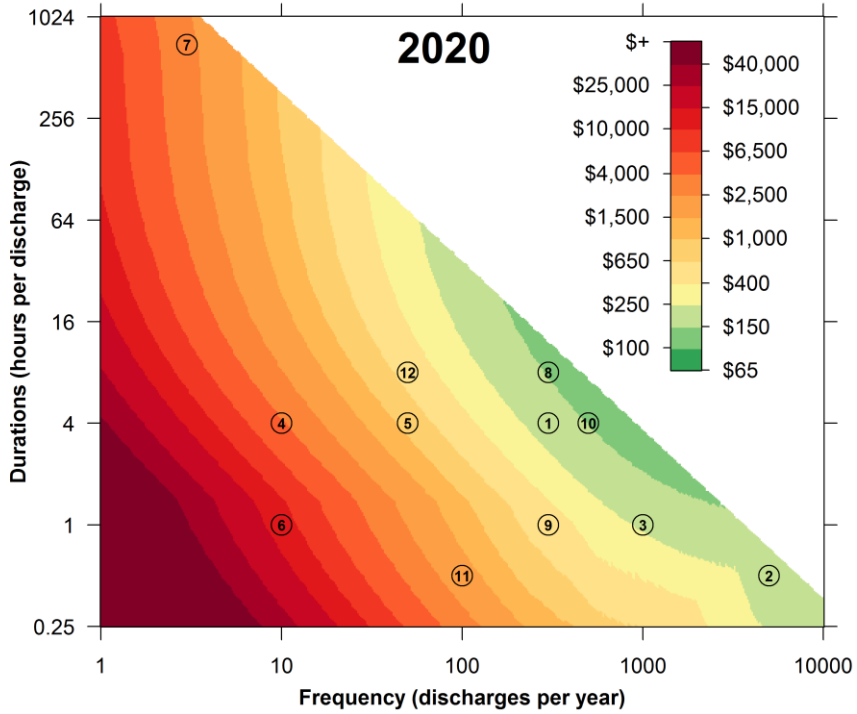
Revenue vs cost (US$/MWh)

Discount rate: 8%
Electricity price: 50 $/MWh

Revenue potential (energy)



Levelised cost of storage

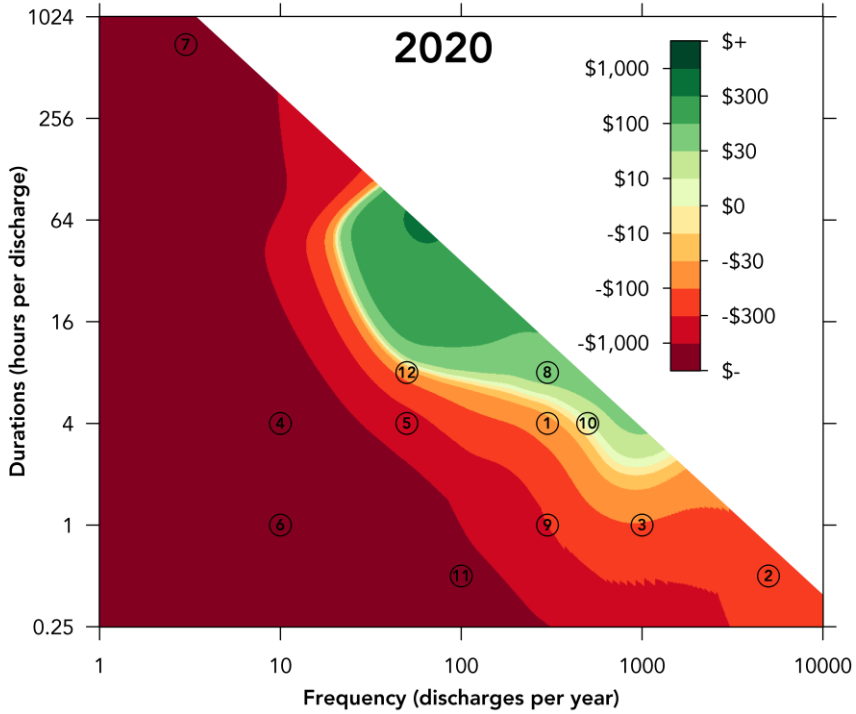


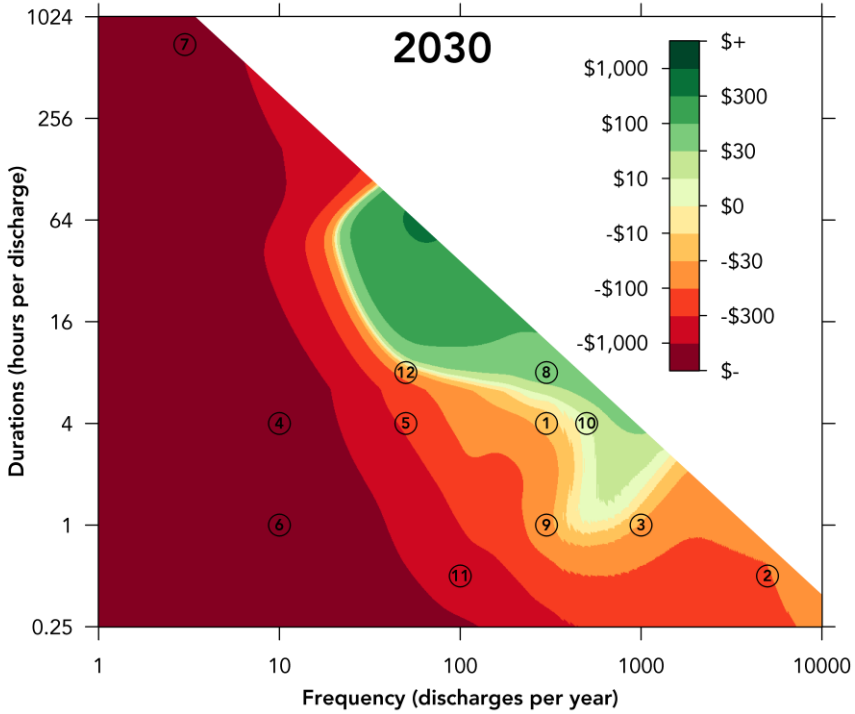
Source: Schmidt, O., Melchior, S., Hawkes, A. & Staffell, I. Projecting the Future Levelized Cost of Electricity Storage Technologies. Joule 3, 1–20 (2019).

…potential business cases for applications with>300 cycles and >1 hour discharge

Profitability in US$/MWh

Discount rate: 8%
Electricity price: 50 $/MWh



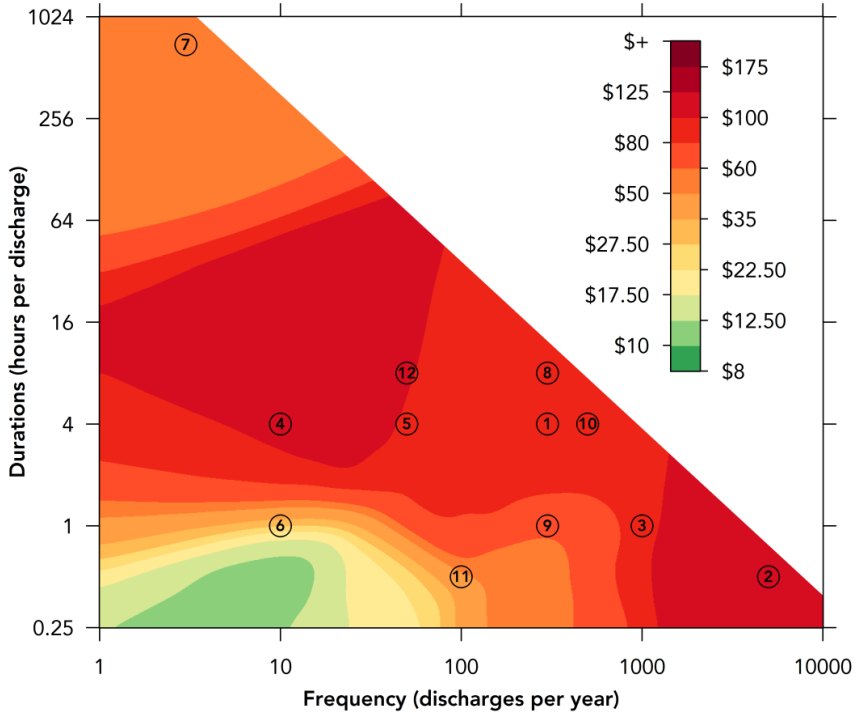


Comparing revenue potential (power) and annuitised capacity cost reveals…

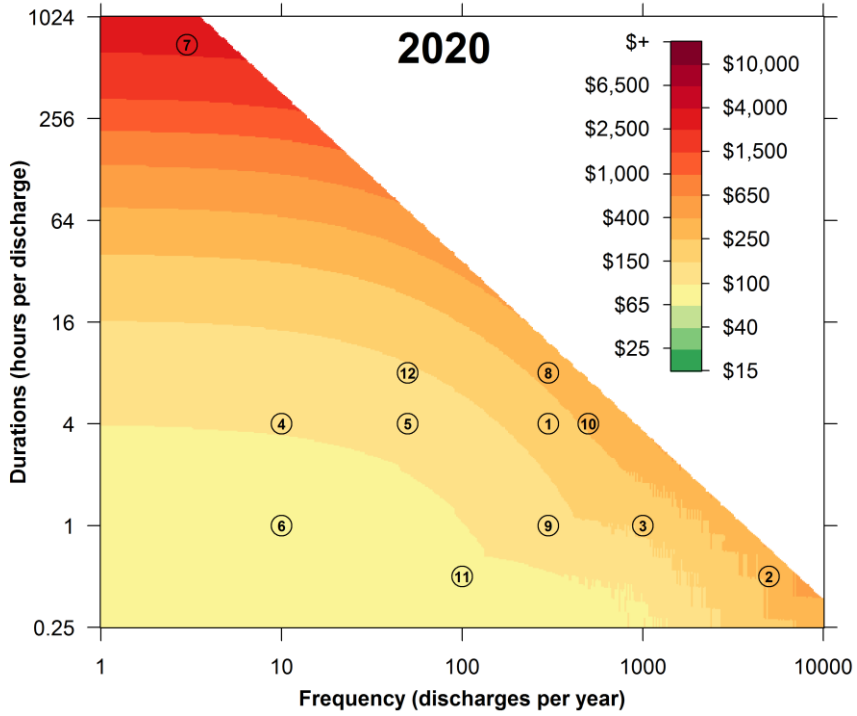
Revenue vs cost (US$/kW$_{year}$)

Discount rate: 8%
Electricity price: 50 $/MWh

Revenue potential (power)



Annuitised capacity cost

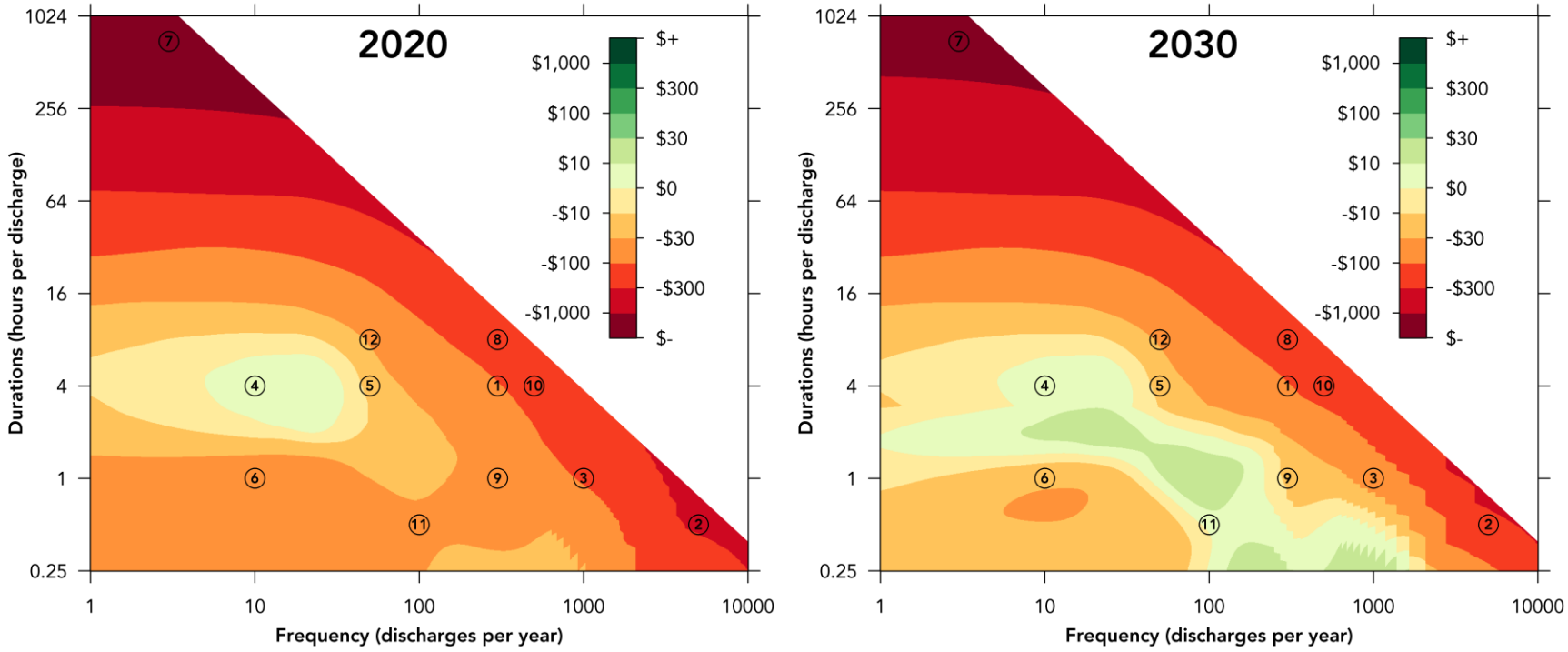


Source: Schmidt, O., Melchior, S., Hawkes, A. & Staffell, I. Projecting the Future Levelized Cost of Electricity Storage Technologies. Joule 3, 1–20 (2019).

… two application categories for potential business cases

Profitability in US$/kW$_{year}$

Discount rate: 8%
Electricity price: 50 $/MWh



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Thank you for your attention!

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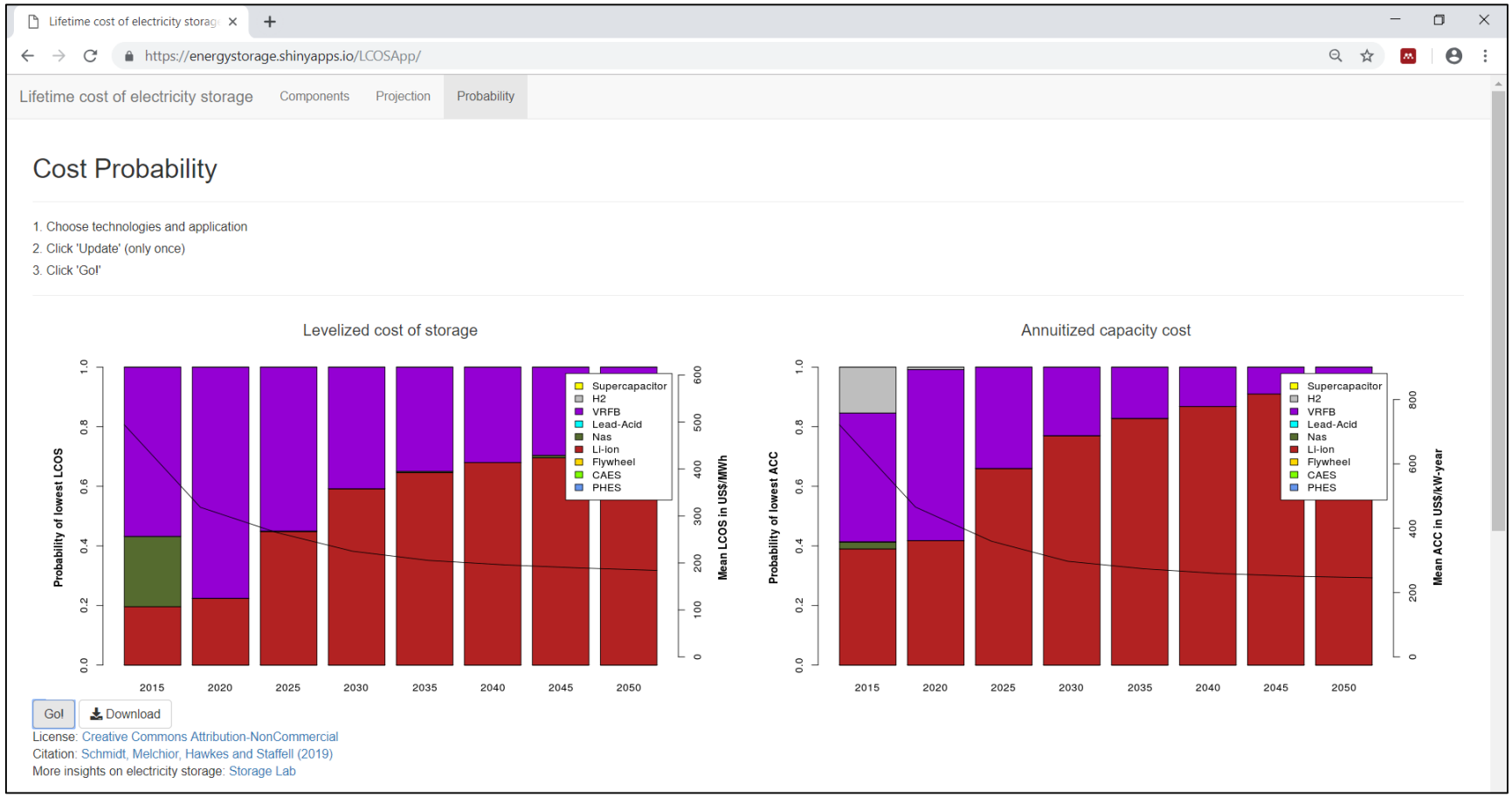
Test your own assumptions on www.EnergyStorage.ninja

Online Tool



All cost and performance parameters relevant during technology life considered

Technology input parameters

			Pumped hydro	Compressed air	Flywheel	Lithium-ion	Sodium-sulphur	Lead-acid	Vanadium redox-flow	Hydrogen	Super-capacitor
Investment cost - Power	$/kW	C_P	1129 (45%)	871 (35%)	641 (17%)	678 (17%)	657 (27%)	675 (23%)	829 (21%)	5417 (48%)	296 (31%)
Investment cost - Energy	$/kWh	C_E	60 (80%)	39 (58%)	5399 (67%)	802 (24%)	738 (12%)	471 (38%)	760 (17%)	31 (60%)	13560 (19%)
Operation cost - Power	$/kW-yr	$C_{P\text{-}OM}$	8 (26%)	4 (23%)	7 (8%)	10 (35%)	11 (50%)	8 (31%)	12 (52%)	46 (30%)	0 (0%)
Operation cost - Energy	$/MWh	$C_{E\text{-}OM}$	1 (60%)	4 (60%)	2 (60%)	3 (60%)	3 (60%)	1 (60%)	1 (60%)	0 (60%)	0 (60%)
Replacement cost	$/kW	$C_{P\text{-}r}$	116 (5%)	93 (5%)	199 (44%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1637 (48%)	0 (0%)
Replacement interval	cycles	Cyc_r	7300	1460	22500	3250	4098	1225	8272	6388	69320
End-of-life cost	%	F_{EOL}	0%	0%	0%	0%	0%	0%	0%	0%	0%
Discount rate	%	DR	8%	8%	8%	8%	8%	8%	8%	8%	8%
Round-trip efficiency	%	η_{RT}	78% (9%)	44% (16%)	88% (3%)	86% (7%)	81% (6%)	84% (0%)	73% (9%)	40% (13%)	91% (6%)
Self-discharge	%/day	$\eta_{self,idle}$	0%	0%	480%	0%	20%	0%	0%	1%	30%
Lifetime (100% DoD)	cycles	Cyc_{life}	33250 (43%)	16250 (20%)	143402 (30%)	3250 (38%)	4098 (29%)	1225 (35%)	8272 (13%)	20000 (0%)	300000 (67%)
Shelf life	years	T_{shelf}	55 (9%)	30 (33%)	18 (14%)	13 (38%)	14 (20%)	10 (50%)	13 (20%)	18 (14%)	14 (33%)
Response time	seconds		>10	>10	<10	<10	<10	<10	<10	<10	<10
Time degradation	%/year	T_{deg}	0.4%	0.7%	1.3%	1.7%	1.6%	2.2%	1.7%	1.3%	1.6%
Cycle degradation	%/cycle	Cyc_{deg}	0.0007%	0.0014%	0.0002%	0.0069%	0.0054%	0.0182%	0.0027%	0.0011%	0.0001%
Construction time	years	T_c	3	2	1	1	1	1	1	1	1
Sources			1,7,12–15	1,7,12–14,16,17	1,3,7,12–14	7,9,13,14,18	1,7,9,13,14,18	1,7,12–14,19,20	1,7,9,13,14	7,13,14,21–24	7,12–14

Impact of depth-of-discharge on cycle life is considered

Depth-of-discharge

Depth-of-Discharge	Pumped hydro	Compressed air	Flywheel	Lithium-ion	Sodium-sulphur	Lead-acid	Vanadium redox-flow	Hydrogen	Super-capacitor
100%	33,250	16,250	143,402	3,250	4,098	1,225	8,272	20,000	300,000
90%	33,250	16,250	143,402	4,875	4,131	1,336	8,272	20,000	300,000
80%	33,250	16,250	143,402	6,297	4,193	1,501	8,272	20,000	300,000
70%	33,250	16,250	143,402	8,531	4,592	1,763	8,272	20,000	300,000
60%	33,250	16,250	143,402	10,766	5,299	2,074	8,272	20,000	300,000
50%	33,250	16,250	143,402	14,219	6,006	2,598	8,272	20,000	300,000
40%	33,250	16,250	143,402	18,586	7,050	3,194	8,272	20,000	300,000
30%	33,250	16,250	143,402	24,984	8,516	4,211	8,272	20,000	300,000
20%	33,250	16,250	143,402	35,953	10,654	6,316	8,272	20,000	300,000
10%	33,250	16,250	143,402	60,734	21,325	13,183	8,272	20,000	300,000
Source				25	26	19			