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Supplementary Information: Lithium Metal Anode Technoeconomic Considerations for Next-Generation Batteries

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Table S1. Parameters for LMA manufacturing with thermal evaporation.

Variable	Description	Value / Distribution and Units	Source and Comments
q_{TE}	Number of thermal evaporators	Set to meet LMB production capacity	
η_{TE}	Thermal evaporator yield	Triangle Distribution: Min = 90% Max = 99% Mode = 98%	¹ Industry interview
γ_{TE}	Max uptime during operational hours	Uniform Distribution: Min = 70% Max = 90%	Unless otherwise stated
d	Deposition rate	Uniform Distribution: Min = 1 $\mu\text{m}/\text{sec}$ Max = 1.3 $\mu\text{m}/\text{sec}$	Industry interview
W_{Te}	Deposition width	0.7 m	Industry interview
L_{Te}	Deposition length	0.2 m	¹
δ	Coating factor	2	Industry interview
$\eta_{Re,TE}$	Recycling rate of lost Li	0	² Industry interview; Assumes recycled Li cannot be directly incorporated with feedstock
D_{TE}	Direct laborers per thermal evaporator	Uniform Distribution: Min = 0.5 Max = 1.5	Industry interview
η_{Th}	Efficiency of heat delivery to Li	Uniform Distribution: Min = 20% Max = 80%	
$p_{Lbr,TE}$	Labor scaling factor	0.85	
E_V	Energy to create vacuum environment	Uniform Distribution: Min: 1 kWh/m ³ Max: 5 kWh/m ³	³
V_V	Volume of vacuum chamber	Uniform Distribution: Min: 0.25 m ³ Max: 0.75 m ³	

V_{Cr}	Crucible volume	Uniform Distribution: Min: 0.01 m ³ Max: 0.03 m ³	¹
γ_{Cr}	Crucible utilization	Triangle Distribution: Min = 75% Max = 85% Mode = 80%	
$p_{Eng,TE}$	Energy scaling factor	0.9	
T_f	Chosen vaporization temperature of Li in vacuum	307° C	⁴
$CapEx_{TE,0}$	Baseline CapEx per thermal evaporator	Uniform Distribution: Min = 2.5 \$ million Max = 5 \$ million	¹ Industry interview
$p_{Cap,TE}$	CapEx scaling factor	0.9	
$G_{k,0}$	Baseline footprint per thermal evaporator	Uniform Distribution: Min = 15 m ² Max = 25 m ²	
$p_{Lnd,TE}$	Land scaling factor	0.95	
$P_{Sub,0}$	Substrate price	Uniform Distribution: PI Min = 3.51 \$/m ² Max = 5.01 \$/m ²	Market data collection
$Area_{Sub,N}$	Baseline substrate area	46,950 m ²	Market data collection
z_{Sub}	Scaling factor, substrate	0.7727 +/- 2 x SE; SE = 0.034	Market data collection, n = 24
$\eta_{Re,Sub}$	Substrate reuse rate	Uniform Distribution: Min = 65% Max = 80%	Industry interview

Table S2. Parameters for LMA manufacturing with extrusion rolling.

Variable	Description	Value / Distribution and Units	Source and Comments
q_{RL}	Number of rollers	Set to meet LMB production capacity	
η_{Ext}	Extruder yield	Uniform Distribution: Min = 90% Max = 98%	
γ_{RL}	Max roller uptime during operational hours	Uniform Distribution: Min = 70% Max = 90%	Unless otherwise stated
W_{ER}	Extrusion rolling width	0.2 m	
t_{Ext}	Extruded thickness	Triangle Distribution: Min = 200 μm Max = 300 μm Mode = 250 μm	Market data collection ⁵
$\alpha_{l,max}$	Maximum roller reduction	Triangle Distribution: Min = 70% Max = 85% Mode = 80%	⁶
D_{Ext}	Direct laborers per extruder	Uniform Distribution: Min = 0.5 Max = 1.0	
$p_{Lbr,Ext}$	Labor scaling factor, extrusion	0.85	
D_{RL}	Direct laborers per roller	Uniform Distribution: Min = 0.5 Max = 1.5	Industry interview
$p_{Lbr,RL}$	Labor scaling factor, extrusion	0.85	
$p_{Eng,Ext}$	Energy scaling factor, extrusion	0.95	
$p_{Eng,RL}$	Energy scaling factor, rolling	0.95	
$CapEx_{Ext,0}$	Baseline CapEx per extruder	Uniform Distribution: Min = 1.5 \$ million Max = 2.5 \$ million	Market data collection
$CapEx_{RL,0}$	Baseline CapEx per roller	Uniform Distribution: Min = 2 \$ million Max = 3.5 \$ million	Market data collection
$p_{Cap,Ext}$	CapEx scaling factor, extrusion	0.9	

$p_{Cap,RII}$	CapEx scaling factor, rolling	0.9	
$G_{Ext,0}$	Baseline footprint per extruder	Uniform Distribution: Min = 5 m ² Max = 10 m ²	
$G_{RII,0}$	Baseline footprint per roller	Uniform Distribution: Min = 10 m ² Max = 20 m ²	
$p_{Lnd,Ext}$	Land scaling factor, extrusion	0.95	
$p_{Lnd,RII}$	Land scaling factor, rolling	0.95	
W_{Blt}	Width Li billet	0.2 m	
Adj_{Ext}	Factor for estimating total extrusion force from force of pressure	Uniform Distribution: Min = 2 Max = 4	6
θ	Half die angle, extruder	Triangle Distribution: Min = 15° Max = 45° Mode = 30°	6
B_{RII}	Diameter of roller	Uniform Distribution: Min = 0.02 m Max = 0.1 m	
λ	Cold/hot rolling parameter	0.3	6
Adj_{RII}	Factor for estimating total rolling force from force of pressure	Uniform Distribution: Min = 2 Max = 4	6
$P_{Lub,0}$	Price of lubricant	Uniform Distribution: Silicon oils (polydimethyl siloxane oligomers) Min = 0.75 \$/kg Max = 1.25 \$/kg	Market data analysis 5,7
B	Lubricant quantity, g per m ² of LMA	Uniform Distribution: Min = 1 g/m ² Max = 10 g/m ²	
$Q_{Lub,0}$	Baseline quantity, lubricant	50,000 kg	Market data analysis
z_{Lub}	Scaling factor, lubricant	0.4233 +/- 2 x SE; SE = 0.1714	Market data analysis, n = 23
$P_{Sub,0}$	Substrate price	Uniform Distribution: Min = 0.01 \$/m ² Max = 0.1 \$/m ²	Market data analysis

$Area_{Sub,N}$	Baseline substrate area	46950 m ²	Market data analysis
z_{Sub}	Scaling factor, substrate	1	Market data analysis
γ_{Ext}	Max extrusion uptime during operational hours	Uniform Distribution: Min = 70% Max = 90%	Unless otherwise stated

Table S3. Additional parameters for LMA manufacturing.

Variable	Description	Value / Distribution and Units	Source and Comments
t	LMA thickness	variable	
P_{Li}	Price of Li	Triangle Distribution: Min = 110 \$/kg Max = 170 \$/kg Mode = 155 \$/kg	⁸ Industry interview
ρ_{Li}	Density of Li	0.534 g/cm ³	
$c_{p,s}$	Specific heat of Li, solid	3.57 kJ/(kg K)	
$\Delta T_{R,m}$	Change in temperature, room temperature to melting point of Li	155° C	
h_f	Heat of fusion of Li	3 kJ/mol	
$c_{p,l}$	Specific heat of Li, liquid	4.169 kJ/(kg K)	⁹
h_v	Heat of vaporization or Li	147 kJ/mol	
T_m	Melting point of Li	180° C	

Table S4. LMB and LMA financial parameters.

Variable	Description	Value / Distribution and Units	Source and Comments
P_{Lbr}	Price of labor	Triangle Distribution: Min = 23.5 \$/hr Max = 55 \$/hr Mode = 37.5 \$/hr	¹⁰
P_{Eng}	Price of electricity	Normal Distribution: Mean = 0.0775 \$/kWh Standard Deviation = 0.039 \$/kWh Minimum bound = 0	¹¹
T	Operational hours per year	Small financial model: T = 300 days * 3 shifts per day * 8 hr shifts = 7200 hrs/year Large financial model: T = 330 days * 3 shifts per day * 8 hr shifts = 7920 hrs/year	¹²
P_{Lnd}	Price of land	Triangle Distribution: Min = 2,000 \$/m ² Max = 4,000 \$/m ² Mode = 3,000 \$/m ²	¹³
$m_{Ovr,Lbr}$	Overhead, percent of labor costs	40%	¹³
$m_{Ovr,Dpr}$	Overhead, percent of depreciation costs	20%	¹³
$m_{GSA,Lbr}$	General, sales, and administration percent of labor costs	25%	¹³
$m_{GSA,Ovr}$	General, sales, and administration percent of overhead costs	25%	¹³
$m_{GSA,Dpr}$	General, sales, and administration percent of depreciation costs	25%	¹³
$m_{R\&D,Dpr}$	Research and development percent of depreciation costs	40%	¹³
s	Percent of total investment paid through equity	Small facility financial model: 60% Large facility financial model: 40%	¹²
r	Interest Rate	Small facility financial model: 12%	¹²

		Large facility financial model: 8%	
T_{Debt}	Loan term	Small facility financial model: 12 years Large facility financial model: 10 years	¹²
T_B	Building lifetime	Small facility financial model: 25 years Large facility financial model: 30 years	¹²
$m_{FCp,Ind}$	Fixed capital, percent of indirect costs	15%	¹³
$m_{Lnc,Mat}$	Launch costs, percent of material costs	Small facility financial model: 5% Large facility financial model: 5%	¹²
$m_{Lnc,Var}$	Launch costs, percent of variable costs	10%	¹³
$m_{Wrk,FCp}$	Working capital, percent of fixed capital	Small facility financial model: 7% Large facility financial model: 5%	¹²

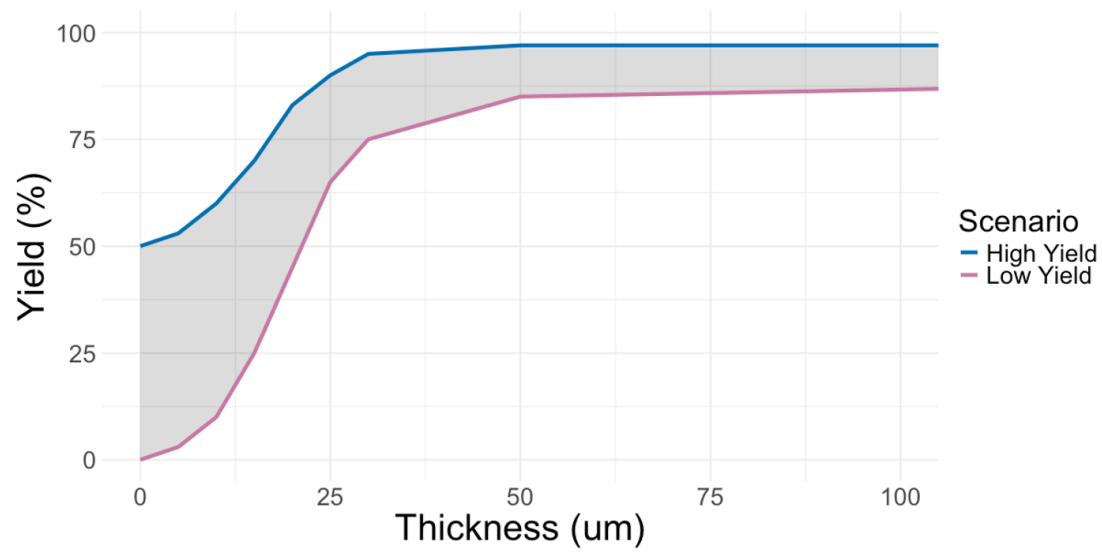


Figure S1. Overall rolling yield distributions vs final LMA thickness.

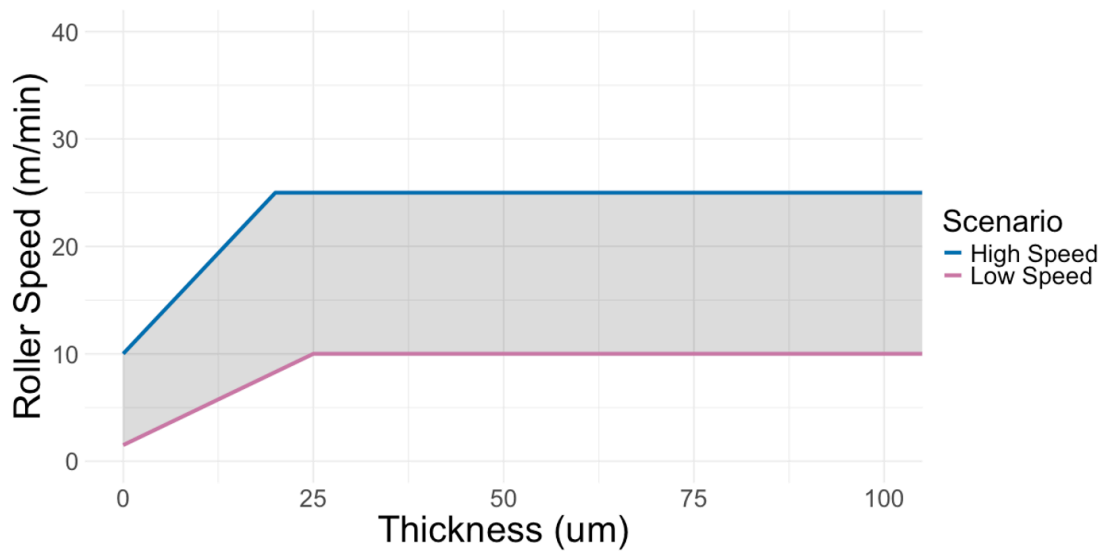


Figure S2. Roller speed distributions vs LMA thickness per pass.

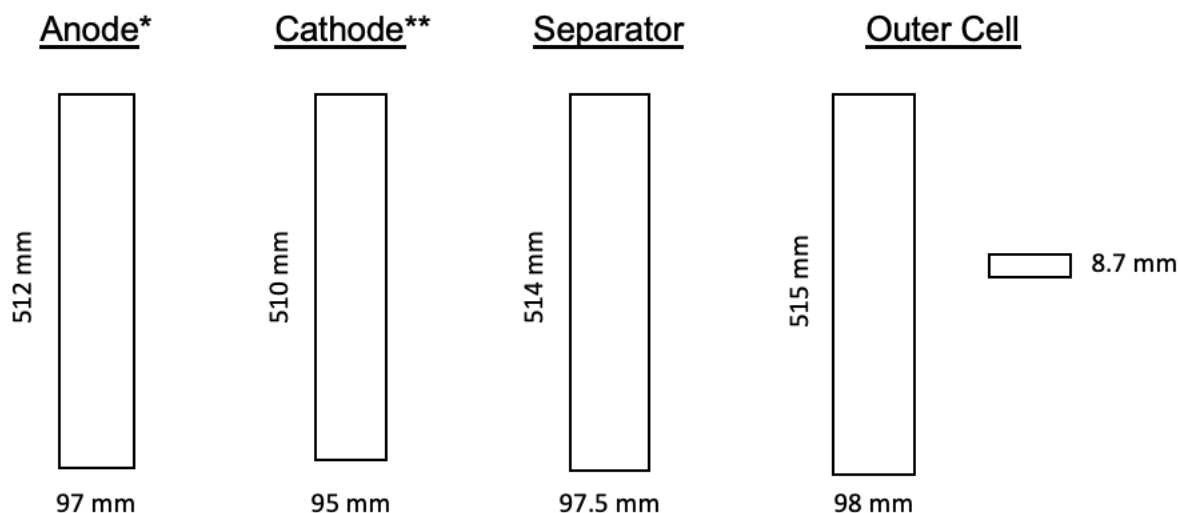


Figure S3. LMB component dimensions. * Anode tab footprint is 45 mm x 40 mm, nickel foil. ** Cathode tab footprint is 45 mm x 40 mm, aluminum foil¹⁴.

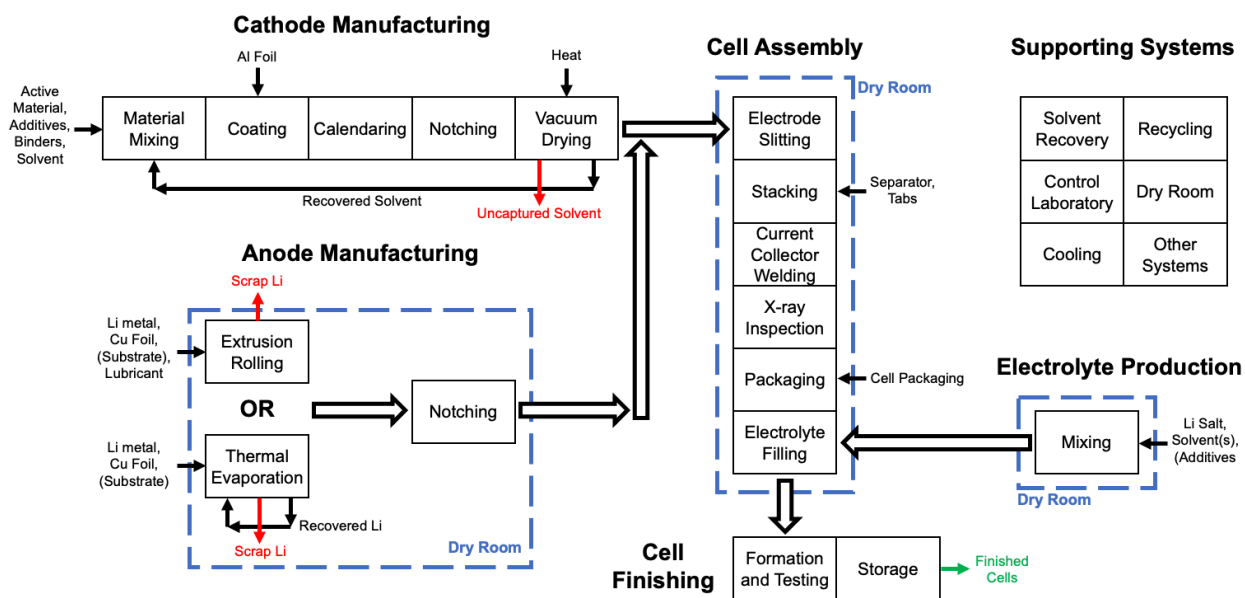


Figure S4. LMB assembly process flow.

Table S5. LMB material and manufacturing parameters.

Variable	Description	Value / Distribution and Units	Source and Comments
N	Annual capacity of a LMB production operation	$N = \begin{cases} 20 \frac{GWh}{year} & \text{for Nth scale} \\ 0.2 \frac{GWh}{year} & \text{for FOAK} \\ 0.002 \frac{GWh}{year} & \text{for (Small)Pilot} \end{cases}$	^{15–18}
$Q_{CAM,0}$	Baseline quantity, cathode active material	70,000,000 kg/year	¹³ , Nth scale
$P_{CAM,0}$	Baseline price, cathode active material	Uniform distribution: Min = 20.76 \$/kg NMC811 Max = 34.61 \$/kg NMC811	¹³ , Mean
z_{CAM}	Scaling factor, cathode active material	1 +/- 2 x SE; SE = 0	No scaling, assumes large existing market of known material
$Q_{CAAd,0}$	Baseline quantity, carbon additive	1,458,333 kg/year carbon black	Derived from cathode composition, Nth scale
$P_{CAAd,0}$	Baseline price, carbon additive	Uniform distribution: Min = 5.93 \$/kg carbon black Max = 9.89 \$/kg carbon black	Market data collection
z_{CAAd}	Scaling factor, carbon additive	0.7036 +/- 2 x SE; SE = 0.0337	Market data collection, n = 8
$Q_{Bnd,0}$	Baseline quantity, binder	1,458,333 kg/year PVDF	Derived from cathode composition, Nth scale
$P_{Bnd,0}$	Baseline price, binder	Uniform distribution: Min = 12.71 \$/kg PVDF Max = 21.19 \$/kg PVDF	Market data collection
z_{Bnd}	Scaling factor, binder	0.5157 +/- 2 x SE; SE = 0.0755	Market data collection, n = 26
$Q_{Slv,0}$	Baseline cathode slurry volume, cathode solvent	40,700,000 L/year NMP	¹³
$P_{Slv,0}$	Baseline price, cathode solvent	Uniform distribution: Min = 2.29 \$/kg NMP Max = 3.81 \$/kg NMP	Market data collection

z_{Slv}	Scaling factor, binder	0.7171 +/- 2 x SE; SE = 0.0701	Market data collection, n = 30
$Q_{CCC,0}$	Baseline cathode area, cathode current collector	303,000,0000 m ² /year aluminum foil	¹³ , Nth scale
$P_{CCC,0}$	Baseline price, cathode current collector	Uniform distribution: Min = 0.17 \$/m ² aluminum foil Max = 0.28 \$/m ² aluminum foil	Market data collection
z_{CCC}	Scaling factor, cathode current collector	0.6238 +/- 2 x SE; SE = 0.1243	Market data collection, n = 20
$Q_{ACC,0}$	Baseline anode area, anode current collector	315,000,0000 m ² /year	¹³ , Nth scale
$P_{ACC,0}$	Baseline price, anode current collector	Uniform distribution: Min = 1.01 \$/m ² copper foil Max = 1.70 \$/m ² copper foil	Market data collection
z_{ACC}	Scaling factor, anode current collector	0.7199 +/- 2 x SE; SE = 0.102	Market data collection, n = 23
$Q_{Sep,0}$	Baseline cathode area, separator	303,000,0000 m ² /year polypropylene film	¹³ , Nth scale
$P_{Sep,0}$	Baseline price, separator	Uniform distribution: Min = 0.77 \$/m ² polypropylene film Max = 1.27 \$/m ² polypropylene film	Market data collection
z_{Sep}	Scaling factor, separator	0.8534 +/- 2 x SE; SE = 0.0943	Market data collection, n = 20
$Q_{ES1,0}$	Baseline volume, electrolyte solvent 1	20 L/year EC	Lab bench scale
$P_{ES1,0}$	Baseline price, electrolyte solvent 1	Uniform distribution: Min = 400 \$/kg EC Max = 1,200 \$/kg EC	Market data collection
z_{ES1}	Scaling factor, electrolyte solvent 1	0.44 +/- 2 x SE; SE = 0.2	¹⁹
$Q_{ES2,0}$	Baseline volume, electrolyte solvent 2	20 L/year DEC	Lab bench scale
$P_{ES2,0}$	Baseline price, electrolyte solvent 2	Uniform distribution: Min = 225 \$/kg DEC Max = 675 \$/kg DEC	Market data collection
z_{ES2}	Scaling factor, electrolyte solvent 2	0.44 +/- 2 x SE; SE = 0.2	¹⁹
$Q_{ESa,0}$	Baseline quantity, electrolyte salt	20 kg/year LiFSI	Lab bench scale
$P_{ESa,0}$	Baseline price, electrolyte salt	Uniform distribution: Min = 5.5 \$/kg LiFSI Max = 16.5 \$/kg LiFSI	Market data collection

z_{ESa}	Scaling factor, electrolyte salt	0.44 +/- 2 x SE; SE = 0.2	19
$Q_{CTb,0}$	Baseline area, cathode tab	310 m ² /year aluminum tab	13
$P_{CTb,0}$	Baseline price, cathode tab	Uniform distribution: Min = 12.75 \$/kg aluminum tab Max =21.25 \$/kg aluminum tab	Market data collection
z_{CTb}	Scaling factor, cathode tab	0.4853 +/- 2 x SE; SE = 0.1027	Market data collection, n = 12
$Q_{ATb,0}$	Baseline area, anode tab	310 m ² /year copper tab	13
$P_{ATb,0}$	Baseline price, anode tab	Uniform distribution: Min = 12.75 \$/kg copper tab Max =21.25 \$/kg copper tab	Market data collection
z_{ATb}	Scaling factor, anode tab	0.4853 +/- 2 x SE; SE = 0.1027	Market data collection, n = 12
$Q_{Pkg,0}$	Baseline area, cell packaging	2,000 m ² /year PA, Aluminum, PP foil	13
$P_{Pkg,0}$	Baseline price, cell packaging	Uniform distribution: Min = 1.65 \$/m ² PA, Aluminum, PP foil Max =2.75 \$/m ² PA, Aluminum, PP foil	Market data collection
z_{Pkg}	Scaling factor, cell packaging	0.4875 +/- 2 x SE; SE =0.1499	Market data collection, n = 26

Table S6. LMB process parameters

Variable	Description	Value / Distribution and Units	Source and Comments
$H_{RRP,0}$	Baseline labor hours, roll to roll processes	720 hrs/year	Market data collection, single roller (assumes nearly automated)
$p_{Lbr,RRP}$	Labor scaling factor, roll to roll processes	0.9	
$R_{RRP,0}$	Baseline power demand, roll to roll processes	1.2 kW	Market data collection, single roller
$p_{Eng,RRP}$	Energy scaling factor, roll to roll processes	0.95	
$CapEx_{RRP,0}$	Baseline CapEx, roll to roll processes	\$2,000	Market data collection, single roller
$p_{Cap,RRP}$	CapEx scaling factor, roll to roll processes	0.9	
$G_{RRP,0}$	Baseline footprint, roll to roll processes	6 m ²	Market data collection, single roller
$p_{Lnd,RRP}$	Land scaling factor, roll to roll processes	0.95	
$Q_{RRP,0}$	Baseline anode area, roll to roll processes	432,000 m ² /year	Market data collection, single roller
$H_{Ant,0}$	Baseline labor hours, anode notching	200,000 hrs/year	¹³ , Nth scale
$p_{Lbr,Ant}$	Labor scaling factor, anode notching	0.7	¹³
$R_{Ant,0}$	Baseline power demand, anode notching	1700 kW	¹³ , Nth scale
$p_{Eng,Ant}$	Energy scaling factor, anode notching	0.95	¹³
$CapEx_{Ant,0}$	Baseline CapEx, anode notching	26.39 \$ million	¹³ , Nth scale
$p_{Cap,Ant}$	CapEx scaling factor, anode notching	0.9	¹³

$G_{ANT,0}$	Baseline footprint, anode notching	3200 m ²	¹³ , Nth scale
$p_{Lnd,ANT}$	Land scaling factor, anode notching	0.95	¹³
$Q_{ANT,0}$	Baseline anode area, anode notching	315,000,000 m ²	¹³ , Nth scale
$H_{CMx,0}$	Baseline labor hours, cathode material mixing	210,000 hrs/year	¹³ , Nth scale
$p_{Lbr,CMx}$	Labor scaling factor, cathode material mixing	0.9	¹³
$R_{CMx,0}$	Baseline power demand, cathode material mixing	6700 kW	¹³ , Nth scale
$p_{Eng,CMx}$	Energy scaling factor, cathode material mixing	0.95	¹³
$CapEx_{CMx,0}$	Baseline CapEx, cathode material mixing	152.04 \$ million	¹³ , Nth scale
$p_{Cap,CMx}$	CapEx scaling factor, cathode material mixing	0.9	¹³
$G_{CMx,0}$	Baseline footprint, cathode material mixing	8600 m ²	¹³ , Nth scale
$p_{Lnd,CMx}$	Land scaling factor, cathode material mixing	0.95	¹³
$Q_{CMx,0}$	Baseline cathode slurry volume, cathode material mixing	40,700,000 L/year	¹³ , Nth scale
$H_{CEC,0}$	Baseline labor hours, cathode electrode coating	59,000 hrs/year	¹³ , Nth scale
$p_{Lbr,CEC}$	Labor scaling factor, cathode electrode coating	0.7	¹³
$R_{CEC,0}$	Baseline power demand, cathode electrode coating	Coater and dryer: 7,200 kW Heating air: 20481.77 kW	¹³ , Nth scale

$p_{Eng,CEC}$	Energy scaling factor, cathode electrode coating	0.95	¹³
$CapEx_{CEC,0}$	Baseline CapEx, cathode electrode coating	76.074 \$ million	¹³ , Nth scale
$p_{Cap,CEC}$	CapEx scaling factor, cathode electrode coating	0.9	¹³
$G_{CEC,0}$	Baseline footprint, cathode electrode coating	16000 m ²	¹³ , Nth scale
$p_{Lnd,CEC}$	Land scaling factor, cathode electrode coating	0.95	¹³
$Q_{CEC,0}$	Baseline cathode area, cathode electrode coating	303,000,000 m ² /year	¹³ , Nth scale
$H_{CCL,0}$	Baseline labor hours, cathode calendaring	47,000 hrs/year	¹³ , Nth scale
$p_{Lbr,CCL}$	Labor scaling factor, cathode calendaring	0.7	¹³
$R_{CCL,0}$	Baseline power demand, cathode calendaring	900 kW	¹³ , Nth scale
$p_{Eng,CCL}$	Energy scaling factor, cathode calendaring	0.95	¹³
$CapEx_{CCL,0}$	Baseline CapEx, cathode calendaring	22.25 \$ million	¹³ , Nth scale
$p_{Cap,CCL}$	CapEx scaling factor, cathode calendaring	0.9	¹³
$G_{CCL,0}$	Baseline footprint, cathode calendaring	2100 m ²	¹³ , Nth scale
$p_{Lnd,CCL}$	Land scaling factor, cathode calendaring	0.95	¹³
$Q_{CCL,0}$	Baseline cathode area, cathode calendaring	303,000,000 m ² /year	¹³ , Nth scale
$H_{CNT,0}$	Baseline labor hours, cathode notching	200,000 hrs/year	¹³ , Nth scale
$p_{Lbr,CNT}$	Labor scaling factor, cathode notching	0.7	¹³

$R_{CNT,0}$	Baseline power demand, cathode notching	1600 kW	¹³ , Nth scale
$p_{Eng,CNT}$	Energy scaling factor, cathode notching	0.95	¹³
$CapEx_{CNT,0}$	Baseline CapEx, cathode notching	26.39 \$ million	¹³ , Nth scale
$p_{Cap,CNT}$	CapEx scaling factor, cathode notching	0.9	¹³
$G_{CNT,0}$	Baseline footprint, cathode notching	1800 m ²	¹³ , Nth scale
$p_{Lnd,CNT}$	Land scaling factor, cathode notching	0.95	¹³
$Q_{CNT,0}$	Baseline cathode area, cathode notching	303,000,000 m ² /year	¹³ , Nth scale
$H_{CVD,0}$	Baseline labor hours, cathode vacuum drying	41,000 hrs/year	¹³ , Nth scale
$p_{Lbr,CVD}$	Labor scaling factor, cathode vacuum drying	0.7	¹³
$R_{CVD,0}$	Baseline power demand, cathode vacuum drying	2600 kW	¹³ , Nth scale
$p_{Eng,CVD}$	Energy scaling factor, cathode vacuum drying	0.85	¹³
$CapEx_{CVD,0}$	Baseline CapEx, cathode vacuum drying	13.58 \$ million	¹³ , Nth scale
$p_{Cap,CVD}$	CapEx scaling factor, cathode vacuum drying	0.9	¹³
$G_{CVD,0}$	Baseline footprint, cathode vacuum drying	1800 m ²	¹³ , Nth scale
$p_{Lnd,CVD}$	Land scaling factor, cathode vacuum drying	0.95	¹³
$Q_{CVD,0}$	Baseline cathode area, cathode vacuum drying	303,000,000 m ² /year	¹³ , Nth scale

$H_{EMx,0}$	Baseline labor hours, electrolyte mixing	210,000 hrs/year	¹³ , Nth scale
$p_{Lbr,EMx}$	Labor scaling factor, electrolyte mixing	0.9	¹³
$R_{EMx,0}$	Baseline power demand, electrolyte mixing	6,700 kW	¹³ , Nth scale
$p_{Eng,EMx}$	Energy scaling factor, electrolyte mixing	0.95	¹³
$CapEx_{EMx,0}$	Baseline CapEx, electrolyte mixing	152.04 \$ million	¹³ , Nth scale
$p_{Cap,EMx}$	CapEx scaling factor, electrolyte mixing	0.9	¹³
$G_{EMx,0}$	Baseline footprint, electrolyte mixing	8,600 m ²	¹³ , Nth scale
$p_{Lnd,EMx}$	Land scaling factor, electrolyte mixing	0.95	¹³
$Q_{EMx,0}$	Baseline mixing volume, electrolyte mixing	40,700,000 L/year	¹³ , Nth scale
$H_{BES,0}$	Baseline labor hours, battery electrode slitting	260,000 hrs/year	¹³ , Nth scale
$p_{BES,k}$	Labor scaling factor, battery electrode slitting	0.7	¹³
$R_{BES,0}$	Baseline power demand, battery electrode slitting	1,700 kW	¹³ , Nth scale
$p_{Eng,BES}$	Energy scaling factor, battery electrode slitting	0.95	¹³
$CapEx_{BES,0}$	Baseline CapEx, battery electrode slitting	67.9 \$ million	¹³ , Nth scale
$p_{Cap,BES}$	CapEx scaling factor, battery electrode slitting	0.9	¹³
$G_{BES,0}$	Baseline footprint, battery electrode slitting	7,700 m ²	¹³ , Nth scale

$p_{Lnd,BES}$	Land scaling factor, battery electrode slitting	0.95	¹³
$Q_{BES,0}$	Baseline total electrode area, battery electrode slitting	618,000,000 m ² /year	¹³ , Nth scale
$H_{BSt,0}$	Baseline labor hours, battery stacking	700,000 hrs/year	¹³ , Nth scale
$p_{Lbr,BSt}$	Labor scaling factor, battery stacking	0.9	¹³
$R_{BSt,0}$	Baseline power demand, battery stacking	4,800 kW	¹³ , Nth scale
$p_{Eng,BSt}$	Energy scaling factor, battery stacking	0.95	¹³
$CapEx_{BSt,0}$	Baseline CapEx, battery stacking	164.9 \$ million	¹³ , Nth scale
$p_{Cap,BSt}$	CapEx scaling factor, battery stacking	0.9	¹³
$G_{BSt,0}$	Baseline footprint, battery stacking	15,000 m ²	¹³ , Nth scale
$p_{Lnd,BSt}$	Land scaling factor, battery stacking	0.95	¹³
$Q_{BSt,0}$	Baseline quantity of full stacks, battery stacking	11,303,000,000	¹³ , Nth scale
$H_{BCW,0}$	Baseline labor hours, battery current collector welding	180,000 hrs/year	¹³ , Nth scale
$p_{Lbr,BCW}$	Labor scaling factor, battery current collector welding	0.9	¹³
$R_{BCW,0}$	Baseline power demand, battery current collector welding	1800 kW	¹³ , Nth scale
$p_{Eng,BCW}$	Energy scaling factor, battery current collector welding	0.95	¹³
$CapEx_{BCW,0}$	Baseline CapEx, battery current collector welding	179.55 \$ million	¹³ , Nth scale

$p_{Cap,BCW}$	CapEx scaling factor, battery current collector welding	0.9	¹³
$G_{BCW,0}$	Baseline footprint, battery current collector welding	3,700 m ²	¹³ , Nth scale
$p_{Lnd,BCW}$	Land scaling factor, battery current collector welding	0.95	¹³
$Q_{BCW,0}$	Baseline accepted cells, battery current collector welding	200,000,000	¹³ , Nth scale
$H_{BXI,0}$	Baseline labor hours, battery x-ray inspection	180,000 hrs/year	¹³ , Nth scale
$p_{Lbr,BXI}$	Labor scaling factor, battery x-ray inspection	0.9	¹³
$R_{BXI,0}$	Baseline power demand, battery x-ray inspection	400 kW	¹³ , Nth scale
$p_{Eng,BXI}$	Energy scaling factor, battery x-ray inspection	0.95	¹³
$CapEx_{BXI,0}$	Baseline CapEx, battery x-ray inspection	12.95 \$ million	¹³ , Nth scale
$p_{Cap,BXI}$	CapEx scaling factor, battery x-ray inspection	0.9	¹³
$G_{BXI,0}$	Baseline footprint, battery x-ray inspection	4600 m ²	¹³ , Nth scale
$p_{Lnd,BXI}$	Land scaling factor, battery x-ray inspection	0.95	¹³
$Q_{BXI,0}$	Baseline accepted cells, battery x-ray inspection	200,000,000	¹³ , Nth scale
$H_{BPK,0}$	Baseline labor hours, battery packaging	490,000 hrs/year	¹³ , Nth scale
$p_{Lbr,BPk}$	Labor scaling factor, battery packaging	0.9	¹³

$R_{BPk,0}$	Baseline power demand, battery packaging	1,000 kW	¹³ , Nth scale
$p_{Eng,BPk}$	Energy scaling factor, battery packaging	0.95	¹³
$CapEx_{BPk,0}$	Baseline CapEx, battery packaging	10.45 \$ million	¹³ , Nth scale
$p_{Cap,BPk}$	CapEx scaling factor, battery packaging	0.9	¹³
$G_{BPk,0}$	Baseline footprint, battery packaging	4,700 m ²	¹³ , Nth scale
$p_{Lnd,BPk}$	Land scaling factor, battery packaging	0.95	¹³
$Q_{BPk,0}$	Baseline accepted cells, battery packaging	200,000,000	¹³ , Nth scale
$H_{BEF,0}$	Baseline labor hours, battery electrolyte filling	130,000 hrs/year	¹³ , Nth scale
$p_{Lbr,BEF}$	Labor scaling factor, battery electrolyte filling	0.9	¹³
$R_{BEF,0}$	Baseline power demand, battery electrolyte filling	2,400 kW	¹³ , Nth scale
$p_{Eng,BEF}$	Energy scaling factor, battery electrolyte filling	0.95	¹³
$CapEx_{BEF,0}$	Baseline CapEx, battery electrolyte filling	23.75 \$ million	¹³ , Nth scale
$p_{Cap,BEF}$	CapEx scaling factor, battery electrolyte filling	0.9	¹³
$G_{BEF,0}$	Baseline footprint, battery electrolyte filling	11,000 m ²	¹³ , Nth scale
$p_{Lnd,BEF}$	Land scaling factor, battery electrolyte filling	0.95	¹³
$Q_{BEF,0}$	Baseline accepted cells, battery electrolyte filling	200,000,000	¹³ , Nth scale

$H_{BDA,0}$	Baseline labor hours, battery dry room airlocks	10,000 hrs/year	¹³ , Nth scale
$p_{Lbr,BDA}$	Labor scaling factor, battery dry room airlocks	0.9	¹³
$R_{BDA,0}$	Baseline power demand, battery dry room airlocks	300 kW	¹³ , Nth scale
$p_{Eng,BDA}$	Energy scaling factor, battery dry room airlocks	0.95	¹³
$CapEx_{BDA,0}$	Baseline CapEx, battery dry room airlocks	6.935 \$ million	¹³ , Nth scale
$p_{Cap,BDA}$	CapEx scaling factor, battery dry room airlocks	0.9	¹³
$G_{BDA,0}$	Baseline footprint, battery dry room airlocks	700 m ²	¹³ , Nth scale
$p_{Lnd,BDA}$	Land scaling factor, battery dry room airlocks	0.95	¹³
$Q_{BDA,0}$	Baseline total electrode volume, battery dry room airlocks	11,303,000,000	¹³ , Nth scale
$H_{Frm,0}$	Baseline labor hours, formation	140,000 hrs/year	Assumes 1/4 th of Li-ion time ¹³ , Nth scale
$p_{Lbr,Frm}$	Labor scaling factor, formation	0.7	BatPac
$R_{Frm,0}$	Baseline power demand, formation	18,000 kW	Assumes 1/4 th of Li-ion power ¹³ , Nth scale
$p_{Eng,Frm}$	Energy scaling factor, formation	1	BatPac
$CapEx_{Frm,0}$	Baseline CapEx, formation	175 \$ million	Assumes 1/4 th of Li-ion CapEx ¹³ , Nth scale
$p_{Cap,Frm}$	CapEx scaling factor, formation	0.95	BatPac

$G_{Frm,0}$	Baseline footprint, formation	27,500 m ²	Assumes 1/4 th of Li-ion footprint ¹³ , Nth scale
$p_{Lnd,Frm}$	Land scaling factor, formation	0.95	¹³
$Q_{Frm,0}$	Baseline accepted cells, formation	200,000,000	¹³ , Nth scale
$H_{Sto,0}$	Baseline labor hours, storage	13,000 hrs/year	¹³ , Nth scale
$p_{Lbr,Sto}$	Labor scaling factor, storage	0.7	¹³
$R_{Sto,0}$	Baseline power demand, storage	7,700 kW	¹³ , Nth scale
$p_{Eng,Sto}$	Energy scaling factor, storage	1	¹³
$CapEx_{Sto,0}$	Baseline CapEx, storage	170 \$ million	¹³ , Nth scale
$p_{Cap,Sto}$	CapEx scaling factor, storage	0.95	¹³
$G_{Sto,0}$	Baseline footprint, storage	10,000 m ²	¹³ , Nth scale
$p_{Lnd,Sto}$	Land scaling factor, storage	0.95	¹³
$Q_{Sto,0}$	Baseline accepted cells, storage	200,000,000	¹³ , Nth scale
$H_{SSR,0}$	Baseline labor hours, support – solvent recovery	14,000 hrs/year	¹³ , Nth scale
$p_{Lbr,SSR}$	Labor scaling factor, support – solvent recovery	0.7	¹³
$R_{SSR,0}$	Baseline power demand, support – solvent recovery	800 kW	¹³ , Nth scale
$p_{Eng,SSR}$	Energy scaling factor, support – solvent recovery	0.7	¹³
$CapEx_{SSR,0}$	Baseline CapEx, support – solvent recovery	24.65 \$ million	¹³ , Nth scale
$p_{Cap,SSR}$	CapEx scaling factor, support – solvent recovery	0.95	¹³

$G_{SSR,0}$	Baseline footprint, support – solvent recovery	900 m ²	¹³ , Nth scale
$p_{Lnd,SSR}$	Land scaling factor, support – solvent recovery	0.95	¹³
$Q_{SSR,0}$	Baseline cathode solvent, support – solvent recovery	24,200,000 kg/year	¹³ , Nth scale
$H_{SRR,0}$	Baseline labor hours, support - rejected cells and scrap recycling	38,000 hrs/year	¹³ , Nth scale
$p_{Lbr,SRR}$	Labor scaling factor, support - rejected cells and scrap recycling	0.7	¹³
$R_{SRR,0}$	Baseline power demand, support - rejected cells and scrap recycling	3400 kW	¹³ , Nth scale
$p_{Eng,SRR}$	Energy scaling factor, support - rejected cells and scrap recycling	1	¹³
$CapEx_{SRR,0}$	Baseline CapEx, support - rejected cells and scrap recycling	7.905 \$ million	¹³ , Nth scale
$p_{Cap,SRR}$	CapEx scaling factor, support - rejected cells and scrap recycling	0.9	¹³
$G_{SRR,0}$	Baseline footprint, support - rejected cells and scrap recycling	3,300 m ²	¹³ , Nth scale
$p_{Lnd,SRR}$	Land scaling factor, support - rejected cells and scrap recycling	0.95	¹³
$Q_{SRR,0}$	Baseline accepted cells, support -	200,000,000	¹³ , Nth scale

	rejected cells and scrap recycling		
$H_{SCL,0}$	Baseline labor hours, support – control laboratory	48,000 hrs/year	¹³ , Nth scale
$p_{Lbr,SCL}$	Labor scaling factor, support – control laboratory	0.7	¹³
$R_{SCL,0}$	Baseline power demand, support – control laboratory	20 kW	¹³ , Nth scale
$p_{Eng,SCL}$	Energy scaling factor, support – control laboratory	1	¹³
$CapEx_{SCL,0}$	Baseline CapEx, support – control laboratory	13.6 \$ million	¹³ , Nth scale
$p_{Cap,SCL}$	CapEx scaling factor, support – control laboratory	0.95	¹³
$G_{SCL,0}$	Baseline footprint, support – control laboratory	1,300 m ²	¹³ , Nth scale
$p_{Lnd,SCL}$	Land scaling factor, support – control laboratory	0.95	¹³
$Q_{SCL,0}$	Baseline process operating power, support – control laboratory	221,073 kW	¹³ , Nth scale
$H_{SDR,0}$	Baseline labor hours, support – dry room	0	¹³ , Nth scale
$p_{Lbr,SDR}$	Labor scaling factor, support – dry room	0	¹³
$R_{SDR,0}$	Baseline power demand, support – dry room	29,000 kW	¹³ , Nth scale
$p_{Eng,SDR}$	Energy scaling factor, support – dry room	0.95	¹³
$CapEx_{SDR,0}$	Baseline CapEx, support – dry room	450.5 hrs/year	¹³ , Nth scale
$p_{Cap,SDR}$	CapEx scaling factor, support – dry room	0.95	¹³

$G_{SDR,0}$	Baseline footprint, support – dry room	0	¹³ , Nth scale
$p_{Lnd,SDR}$	Land scaling factor, support – dry room	0	¹³
$Q_{SDR,0}$	Baseline dry room area, support – dry room	47,400 m ²	¹³ , Nth scale
$H_{SCg,0}$	Baseline labor hours, support - cooling	0 hrs/year	¹³ , Nth scale
$p_{Lbr,SCg}$	Labor scaling factor, support - cooling	0	¹³
$R_{SCg,0}$	Baseline power demand, support - cooling	29,000 kW	¹³ , Nth scale
$p_{Eng,SCg}$	Energy scaling factor, support - cooling	0.95	¹³
$CapEx_{SCg,0}$	Baseline CapEx, support - cooling	510 \$ million	¹³ , Nth scale
$p_{Cap,SCg}$	CapEx scaling factor, support - cooling	0.95	¹³
$G_{SCg,0}$	Baseline footprint, support - cooling	0 m ²	¹³ , Nth scale
$p_{Lnd,SCg}$	Land scaling factor, support - cooling	0	¹³
$Q_{SCg,0}$	Baseline process operating power, support - cooling	221,073 kW	¹³ , Nth scale
$H_{SOS,0}$	Baseline labor hours, support – other systems	0 hrs/year	¹³ , Nth scale
$p_{Lbr,SOS}$	Labor scaling factor, support - other systems	0	¹³
$R_{SOS,0}$	Baseline power demand, support – other systems	27,000 kW	¹³ , Nth scale
$p_{Eng,SOS}$	Energy scaling factor, support – other systems	0.95	¹³
$CapEx_{SOS,0}$	Baseline CapEx, support – other systems	467.5 \$ million	¹³ , Nth scale

$p_{Cap,SOS}$	CapEx scaling factor, support – other systems	0.95	¹³
$G_{SOS,0}$	Baseline footprint, support – other systems	0	¹³ , Nth scale
$p_{Lnd,SOS}$	Land scaling factor, support – other systems	0	¹³
$Q_{SOS,0}$	Baseline accepted cells, support – other systems	200,000,000	¹³ , Nth scale

Discussion S1. Additional representative design details.

Cathode design and manufacturing¹³

The NMC811 cathodes present in the pouch cells are modeled as 96% (by weight) cathode active material, 2% binder (PVDF), and 2% carbon black. The ratio of solvent (NMP) mass to binder mass is 16:1 during cathode manufacturing. 99.5% of the solvent is recovered during drying. Void volume of the cathode is 27%.

Electrolyte design of a representative LMB

We strategically choose mature solvents and salts in the electrolyte for the representative LMB in order to mitigate the high variability of current electrolyte design in current LMBs and the high uncertainty of electrolyte design for future LMBs. We note that this decision may not accurately reflect the true design of electrolytes into the future especially considering the known challenges associated in LMBs using the selected electrolyte materials. However, the use of mature materials in our representative cell provides a baseline price representative of a fully scaled electrolyte manufacturing sector. We model an EC:DEC solvent with a molar ratio of 1.34:1, with a highly concentrated 10 M LiFSI salt²⁰. Electrolyte mass per cell is modeled as 3 g/Ah, a value once again selected to reflect mature cell technology despite the current challenges with cycle life a lean, highly concentrated electrolyte design may have²¹. Variability in electrolyte design is capture in the Figure 5b and c, as well as Figure S7.

Cell packaging design

The pouch cell packaging is modeled as 80 μm thick, 20% polyamide, 40% aluminum, and 40% polypropylene by thickness.

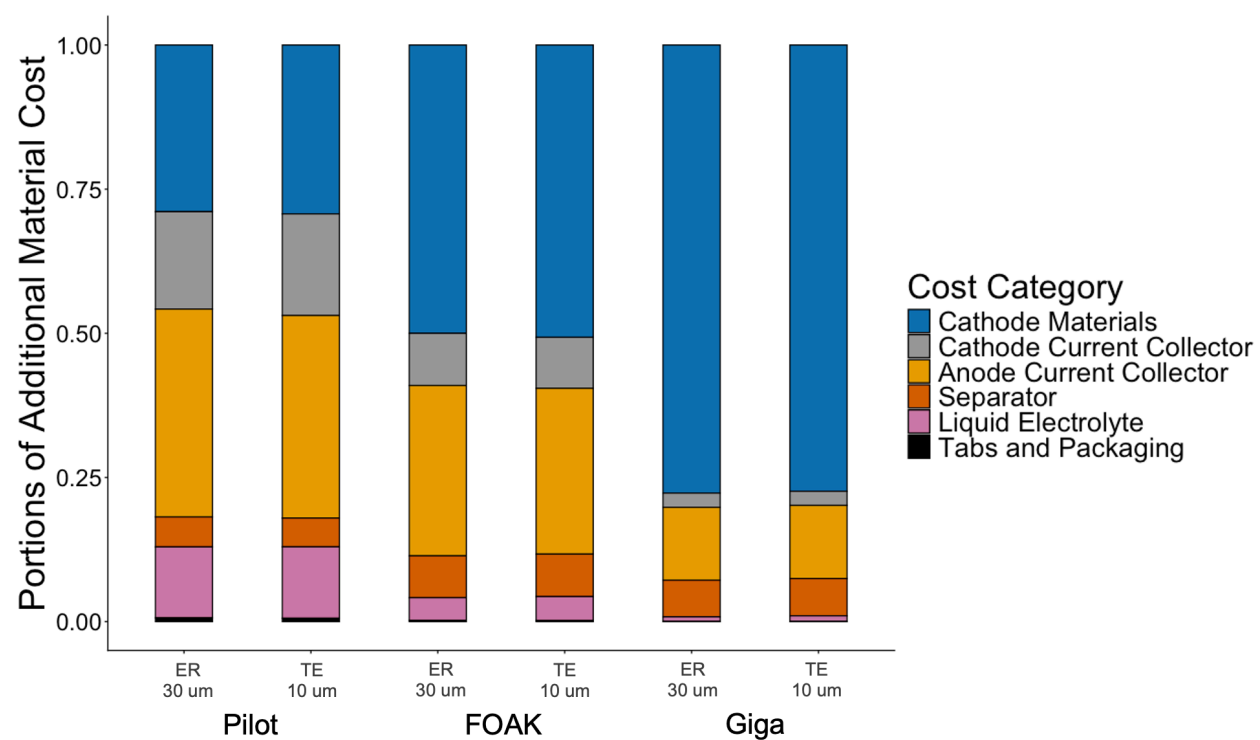


Figure S5. Breakdown of additional material costs for representative LMBs.

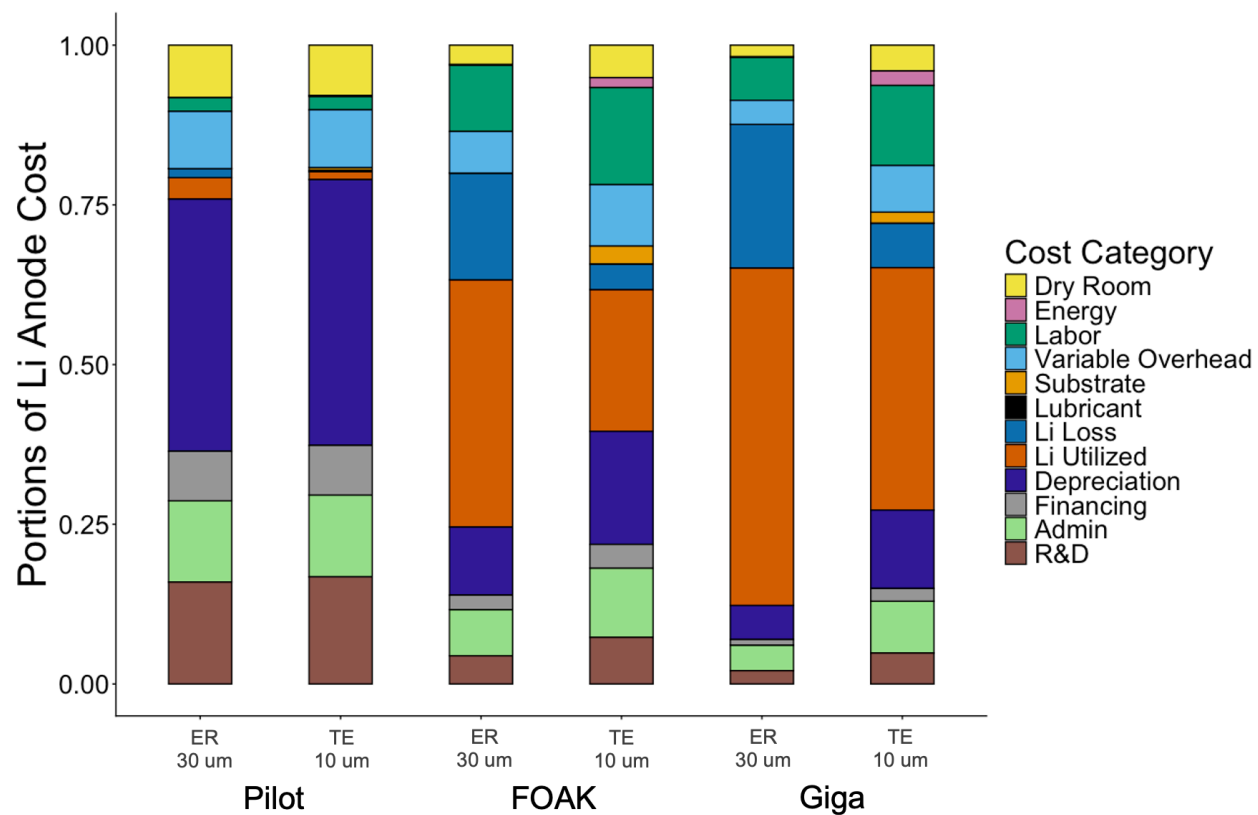


Figure S6. Breakdown of Li anode costs for representative LMBs.

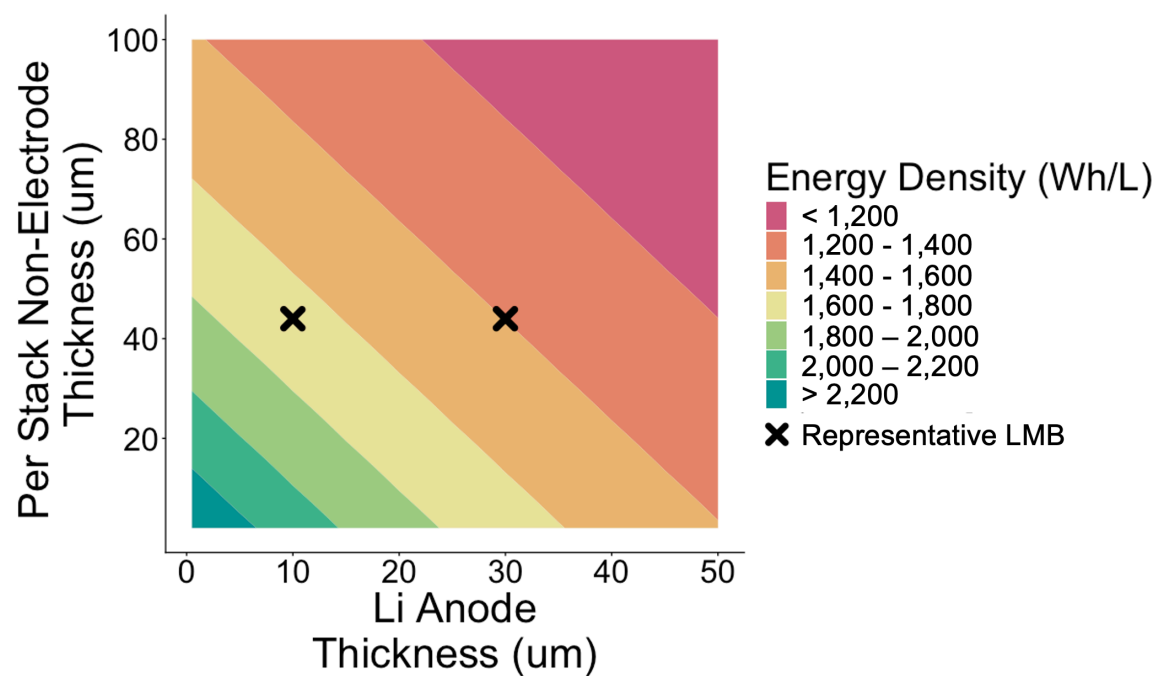


Figure S7. LMB energy density as a function of non-electrode component thickness and LMA thickness.

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