

Supporting Information

Economic Analysis of CNT Lithium-Ion Battery Manufacturing

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Satellite Battery			
Operation Data	Battery production volume	3,000	Battery/year
	Production volume	300,000	Cells/year
	Total production volume	376,882	Cells/year
	Electrode conversion	95%	%
	Assembly conversion	95%	%
	Process yield	Stochastic	%
	Final assembly yield	98%	%
	Hours per day	24	hrs
	Scheduled downtime	1.5	hrs
	Interest rate	10%	%
	Building life	30	years
	Days per Year	250	days
	Energy cost	Stochastic	\$/KWh
	Labor cost	25	\$/hr
	Indirect labor rate	20	\$/hr
	% Indirect labor added on	15%	%
	Auxillary equipment rate	10%	%
	Installation equipment rate	2%	%
	Tools rate	25%	%
	Fixed overhead rate	40%	%
	Maintenance Rate	5%	%
	Building cost	73	\$/sq. ft
	Total number of cells / battery	100	cells
	Total Time per year	5,625	hrs

1 - Cathode & Anode Mixing			
Cathode Material Input (in mixer)			
	% of cathode active material	55	%
	% of NMP	40	%
	% of PVDF	2	%
	% of MWCNT	1	%
	% of carbon black	2	%
Cathode Material Input / cell			
	Cathode active material (NMC)	0.307	kg
	PVDF	0.034	kg
	MWCNT	0.016	kg
	Carbon black	0.018	kg
	Total cathode weight	0.375	kg
	NMP	0.106	kg
	Sodium hydroxide	0.005	kg
	Sulphuric acid	0.003	kg
	Cost of cathode active material	15	\$/kg
	Cost of NMP	4	\$/kg
	Cost of PVDF	20	\$/kg
	Cost of MWCNT	Stochastic	\$/kg
	Cost of carbon black	10	\$/kg
	Cost of sodium hydroxide	0.30	\$/kg
	Cost of sulphuric acid	0.48	\$/kg
Anode Material Input (in mixer)			
	% of anode active material	45	%
	% of NMP	10	%
	% of Carbon black	5	%
	% Deionized water	40	%
Anode Material Input / cell			
	Anode active material(Graphite+latex)	0.024	kg
	Carbon black	0.017	kg
	Total anode weight	0.250	kg
	NMP	0.078	kg
	Deionized water	0.105	kg
	Sodium hydroxide	0.009	kg
	Sulphuric acid	0.006	kg
	Cost of anode active material	20	\$/kg

	Cost of NMP	4	\$/kg
	Cost of PVDF	20	\$/kg
	Cost of deionized water	3.785	\$/kg
	Cost of sodium hydroxide	0.30	\$/kg
	Cost of sulphuric acid	0.48	\$/kg
Labor			
	Number of labor	3	worker/line
Equipment			
	Cost of primary equipment (mixer)	7,800	\$
	Power rating of mixer	30	kw
	Lifespan of mixer	15	yrs
	Process time per cell	0.0047	hrs
Facility			
	Floor space used	80	sq. ft

2 - Cathode & Anode Coating + Baking			
Cathode Material Input / cell			
	Aluminum sheet	0.017	kg
	Cost of aluminum	10	\$/kg
Anode Material Input / cell			
	Copper sheet	0.051	kg
	Cost of copper	15	\$/kg
Labor			
	Number of labor	3	worker/line
Equipment			
	Cost of primary equipment (coater)	20,000	\$
	Power rating of machine	120	kw
	Lifespan of machine	8	yrs
	Process time per cell	0.0002	hrs/cell
Facility			
	Floor space used	250	sq. ft

3 - Calendaring (Pressing)			
Material Input / cell			
Labor			
	Number of labor	3	Worker/line
Equipment			
	Cost of primary equipment	20,000	\$
	Power rating of machine	20	kw
	Lifespan of machine	8	yrs
	Process time per cell	0.0002	hrs/cell
Facility			
	Floor space used	250	sq. ft

4 - Cutting			
Material Input / cell			
	Separator (Aluminum)	0.034	kg
	Cost of separator	10	\$/kg
Labor			
	Number of labor	3	Worker/line
Equipment			
	Cost of primary equipment	40,000	\$
	Power rating of machine	25	kw
	Lifespan of machine	10	yrs
	Process time per cell	0.00003	hrs/cell
Facility			
	Floor space used	300	sq. ft

5 - Assembling (stacking & winding)

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Material Input / cell			
	Can / Case (aluminum)	0.017	kg
	Cost of case	10	\$/kg
Labor			
	Number of labor	3	Worker/line
Equipment			
	Cost of primary equipment	20,000	\$
	Power rating of machine	25	kw
	Lifespan of machine	10	yrs
	Process time per cell	0.003	hrs/cell
Facility			
	Floor space used	300	sq. ft

6 - Wetting or Filling

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Material Input / cell			
	Electrolyte	0.17	kg
	Cost of electrolyte	20	\$/kg
Labor			
	Number of labor	3	Worker/line
Equipment			
	Cost of primary equipment	10,000	\$
	Power rating of machine	25.0	kw
	Lifespan of machine	10	yrs
	Process time per cell	0.0003	hrs/cell
Facility			
	Floor space used	300	sq. ft

7 - Sealing & Welding			
Material Input / cell			
Labor			
	Number of labor	3	Worker/line
Equipment			
	Cost of primary equipment	30,000	\$
	Power rating of machine	30	kw
	Lifespan of machine	10	yrs
	Process time per cell	0.0003	Hrs/cell
Facility			
	Floor space used	300	sq. ft

8 - Forming & Grading& Testing			
Material Input / cell			
Labor			
	Number of labor	0.609	Worker/line
Equipment			
	Cost of primary equipment	12,000	\$/line
	Power rating of machine	6	kw
	Lifespan of machine	10	yrs
	Process time (per 512 Cells)	Stochastic	hrs
Facility			
	Floor space used	250	sq. ft

9 - Final Assembly			
Material Input / battery			
Module container			
	Aluminum /per module	3.43	kg
Battery pack container			
	Steel	28.756	kg
	Copper wiring	2.157	kg
	Steel	2.157	kg
	Printed circuit board		kg
Passive cooling system			
	Aluminum	28.756	kg
	Cost of steel	1	\$/kg
	Cost of aluminum	10	\$/kg
	Cost of copper wiring	15	\$/kg
	Cost of printed circuit board (cell connecting)		\$/cell
Labor			
	Number of labor	3	worker
Equipment			
	Cost of primary equipment	25,000	\$
	Power rating of machine	15	kw
	Lifespan of machine	10	yrs
	Process time per battery	0.1	hrs/battery
Facility			
	Floor space used	500	sq. ft

Safety Parameters			
Ventilation			
General exhaust ventilation (GEV)			
	Air changes/hr (nanomanufacturing)	25	AC/hr
	Total floor space needed	3,839	sq. ft
	Soace height	20	sq. ft
	Space volume (w* ht* t)	76,785	cu.ft
	Ventilation rate	31,994	cfm
	Capital cost	25	\$/cfm
	Operating cost	7	\$/cfm/yr
	Lifespaan	10	yrs
Local exhaust ventilation (LEV)			
	Total number of lines needed LEV	9	lines
	Fume hoods	18,000	\$
	HEPA filter cost	299	\$
	Number of filters needed for each LEV	4	filters
	Maintenance cost	5%	%
	Extra labor cost	25%	%
	Fumehood power rating	10	kw
	Fume hood life span	10	yrs
Enclosure of processes			
	Cost of enclosure - extra equipment cost	50%	%
	Maintenance cost	20%	%
	Cost of enclosure - extra labor cost	50%	%
Insurance			
	Cost of insurance	1%	%
Personal protection equipment			
	Total number of workers	21	pairs
	1- Latex gloves		
	Cost of pair of Latex gloves	0.13	\$/pair
	2- Nitrile gloves		
	Cost of pair of Nitrile gloves	0.19	\$/pair
	3- Disposable respirators		
	Cost of Disposable respirators	1.1	\$/mask
	4- Respirators with HEPA filters		
	Cost of HEPA mask	29	\$/mask
	Cost of HEPA filters	10	\$/pair
	Usage period for HEPA filters	30	hrs

	5- Tyvek suits		
	Cost of Tyvek suits	6	\$/suit
	6- Hazardous waste of PPE		
	Weight of pair of Nitrile gloves	0.05	lb
	Weight of HEPA filters	1.25	lb
	Weight of Tyvek suit	0.50	lb
	Cost of disposal of hazardous waste of PPE	Stochastic	\$/lb
Administrative Control			
	Cost of Air Monitoring Equipment	20,000	\$
	Power rating of machine	30	kw
	Operating cost for air monitoring	20%	%
	Cost of medical monitoring	950	\$/person/yr
	Lifespan of machine	10	yrs
	Frequency of Air Monitoring		
	Low case	12	days/yr
	Medium case	52	days/yr
	High case	104	days/yr