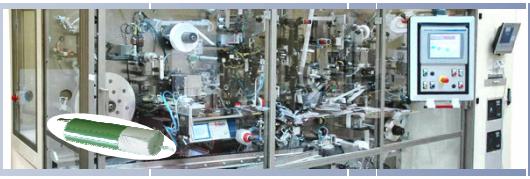
ARCOTRONICS INDUSTRIES
KEMET Electronics Italia



The Capacitance Company
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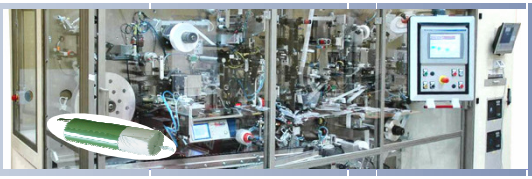
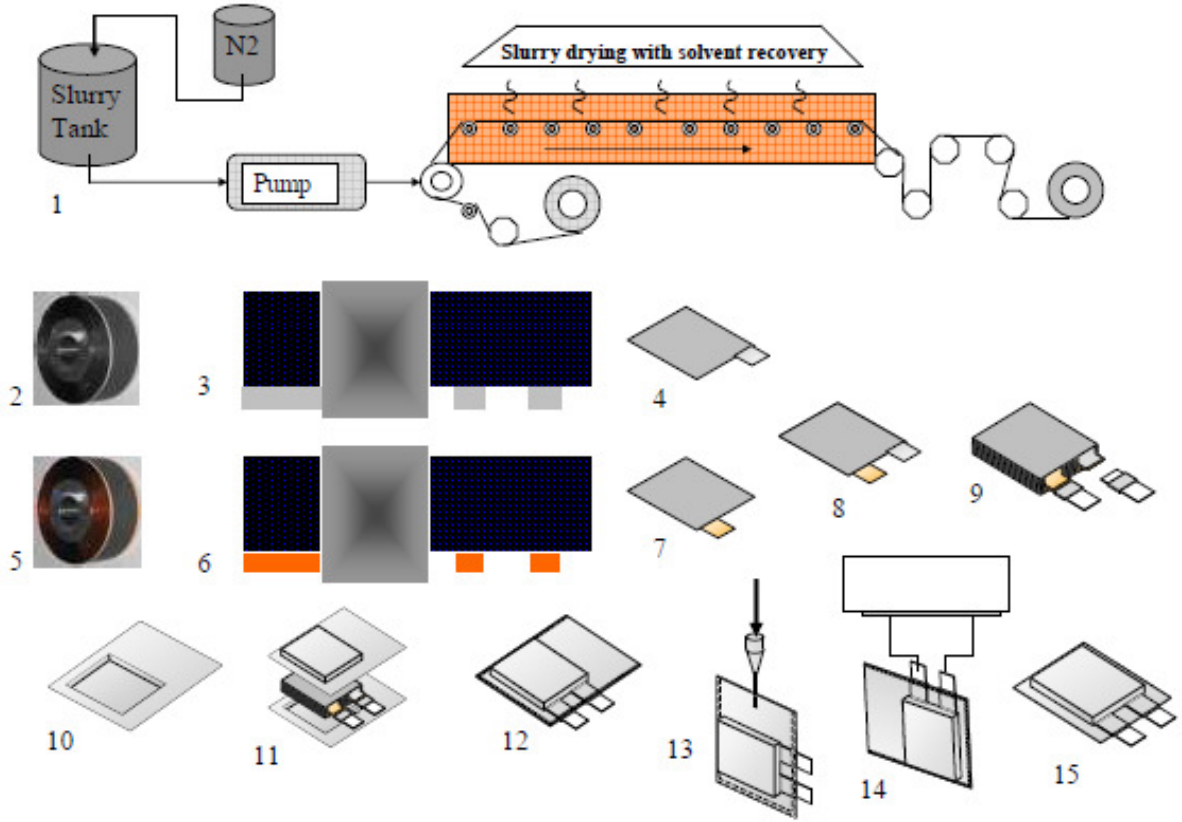
Cell Production Technologies and Perspectives on Cost vs. Volume

C.Lanciotti , S.Saguatti , F.Nanni ,
J.Dispennette

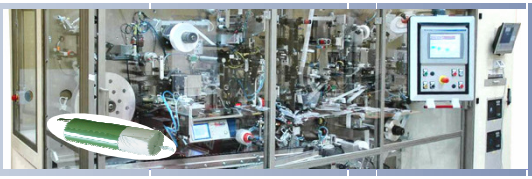
Joint EC / EPoSS / ERTRAC Expert Workshop 2010
"Electric Vehicle Batteries Made in Europe"



Overview of a Typical Soft Pack Lithium Battery Cell Production Flow

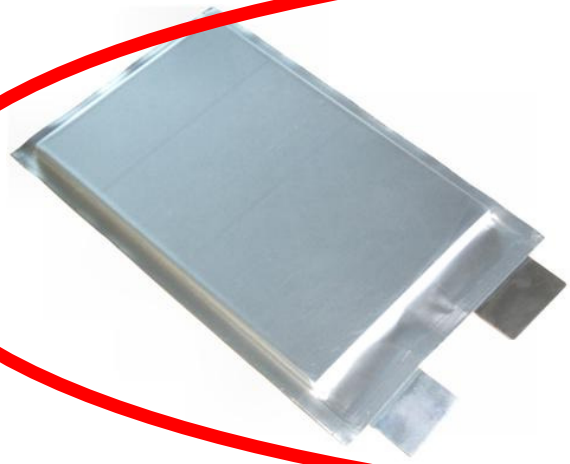


1Mixing and coating 2Cathode Electrode Roll 3Cathode Tab Notching 4Cathode Electrode 5Anode Electrode Roll 6Anode Tab Notching 7Anode Electrode 8Mono-cell Assembly	9. Mono-cell Stacking and Tab Welding 10. Pouch Extrusion 11. Stacked Cells Packaging 12. Pouch Sealing with Provision for Formation Gas Pouch 13. Electrolyte Injection 14. Formation Cycles 15. Degassing , Gas Pouch Removal and Final Sealing

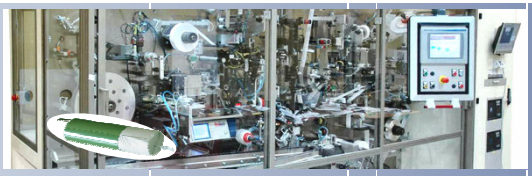


Large Battery Formats

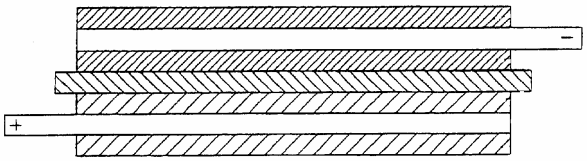
Wound	High manufacturing throughput
	High packaging costs
	Low packing density
Baseline Process	Continuous feeding of materials



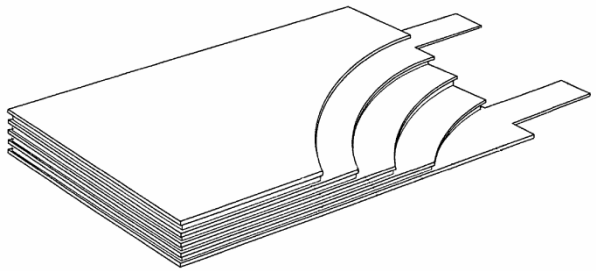
Prismatic	Low manufacturing throughput
	Low packaging costs
	High packing density
Baseline Process	Index feeding of materials



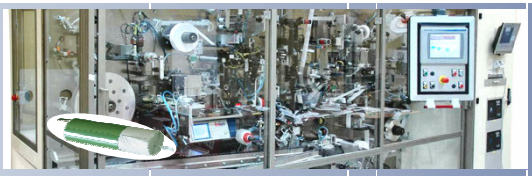
Traditional Approach for Prismatic Assembly is Stacking



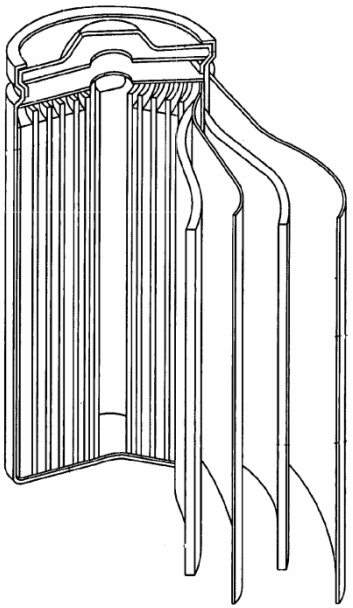
Process	Each layer (anode, separator, cathode) pick and placed
	Multi-layer precision placement difficulties
	Long cycle time

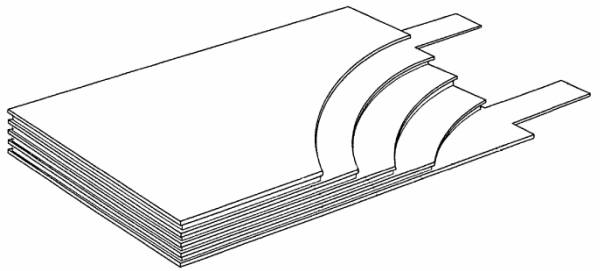


Improved manufacturing methods required to make product cost effective

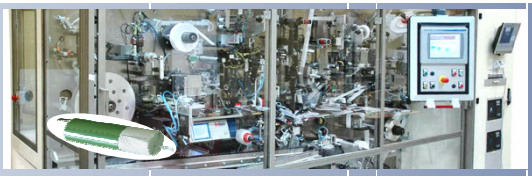


Is it possible to combine Winding with Stacking?

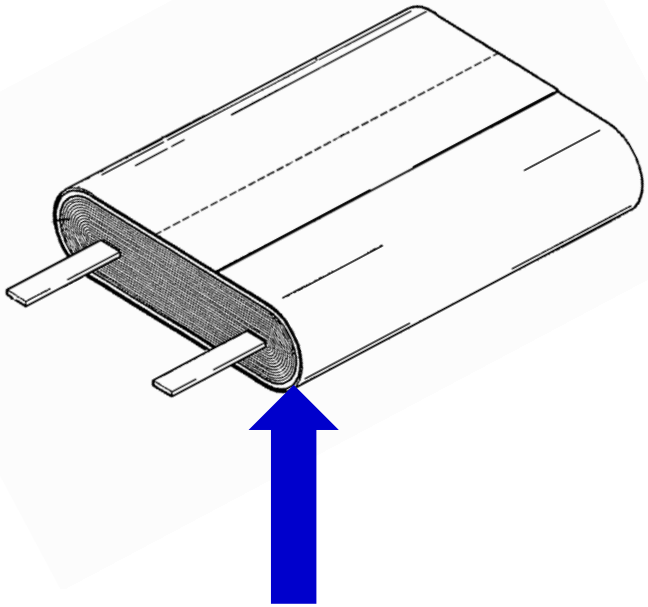




***TARGET:* Integrate the best of both**



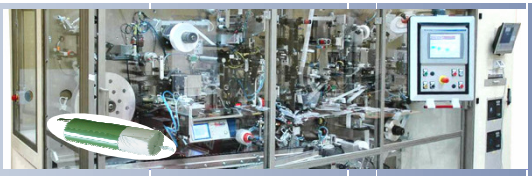
Approach 1:



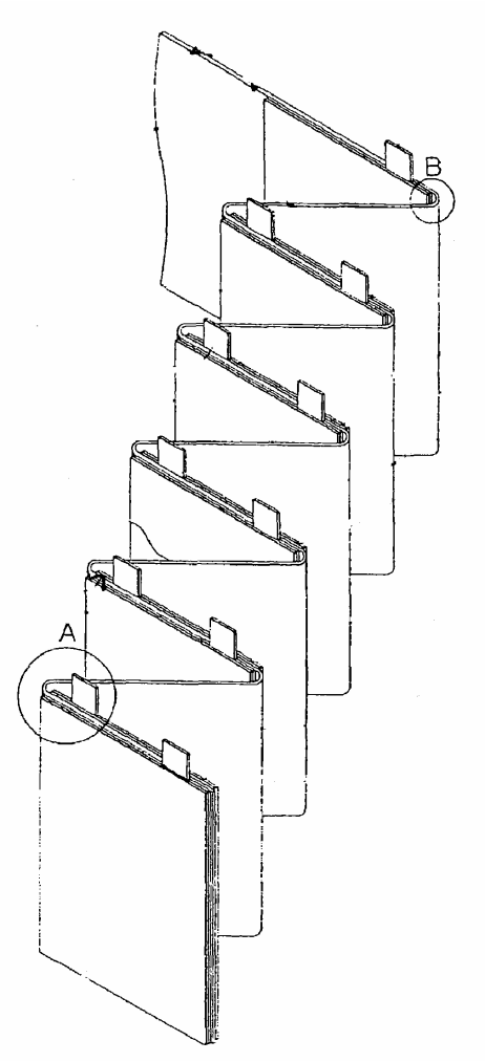
Prismatic Winding	Improved manufacturing throughput compared to Stacking
	Similar packaging costs to winding
	Improved packing density compared to winding
Process	Continuous feeding of materials

Main technical concern is stressing of electrodes in corners

What can be done to refine further?



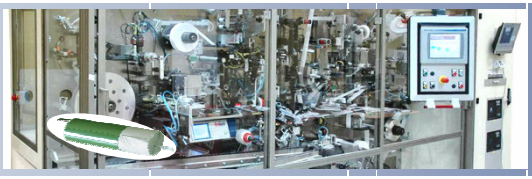
Approach 2:



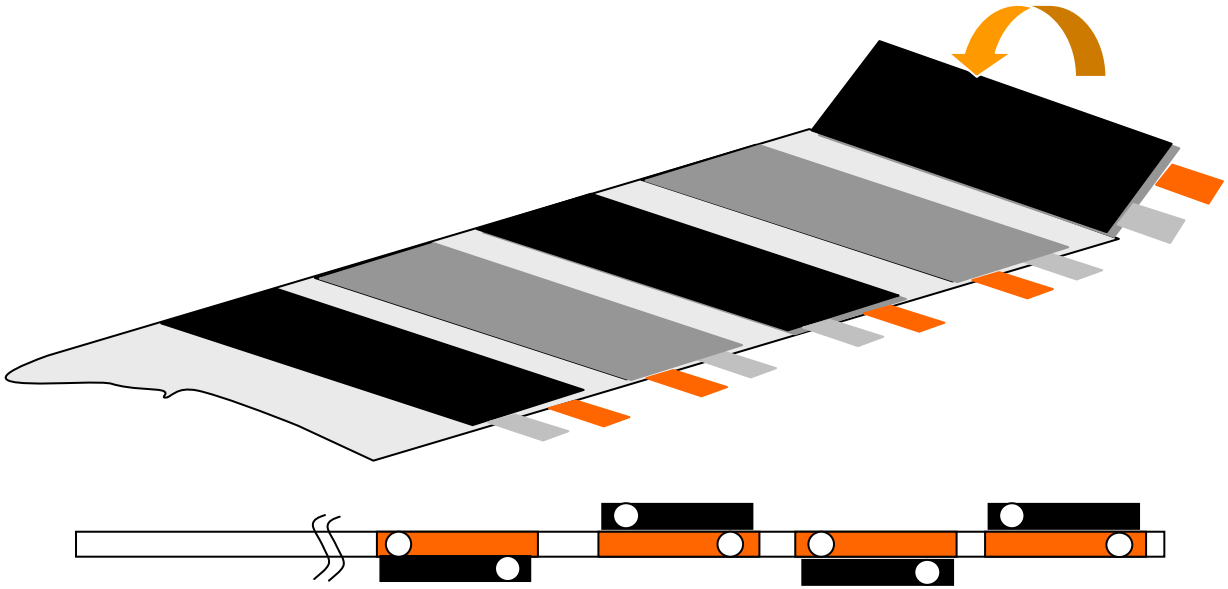
Z – Folding	**Improved manufacturing throughput compared to Stacking**
	Utilize same packaging as Stacking
	Same packaging density as Stacking

Process	**Alternating electrodes, continuous separator**

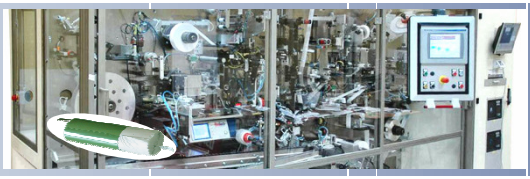
A good solution…can we do better?



An Innovative Solution – Stack Winding



Incorporates continuous process of Winding with volumetric efficiency and energy density of Stacking.



ASSEMBLY PROCESS FLOW

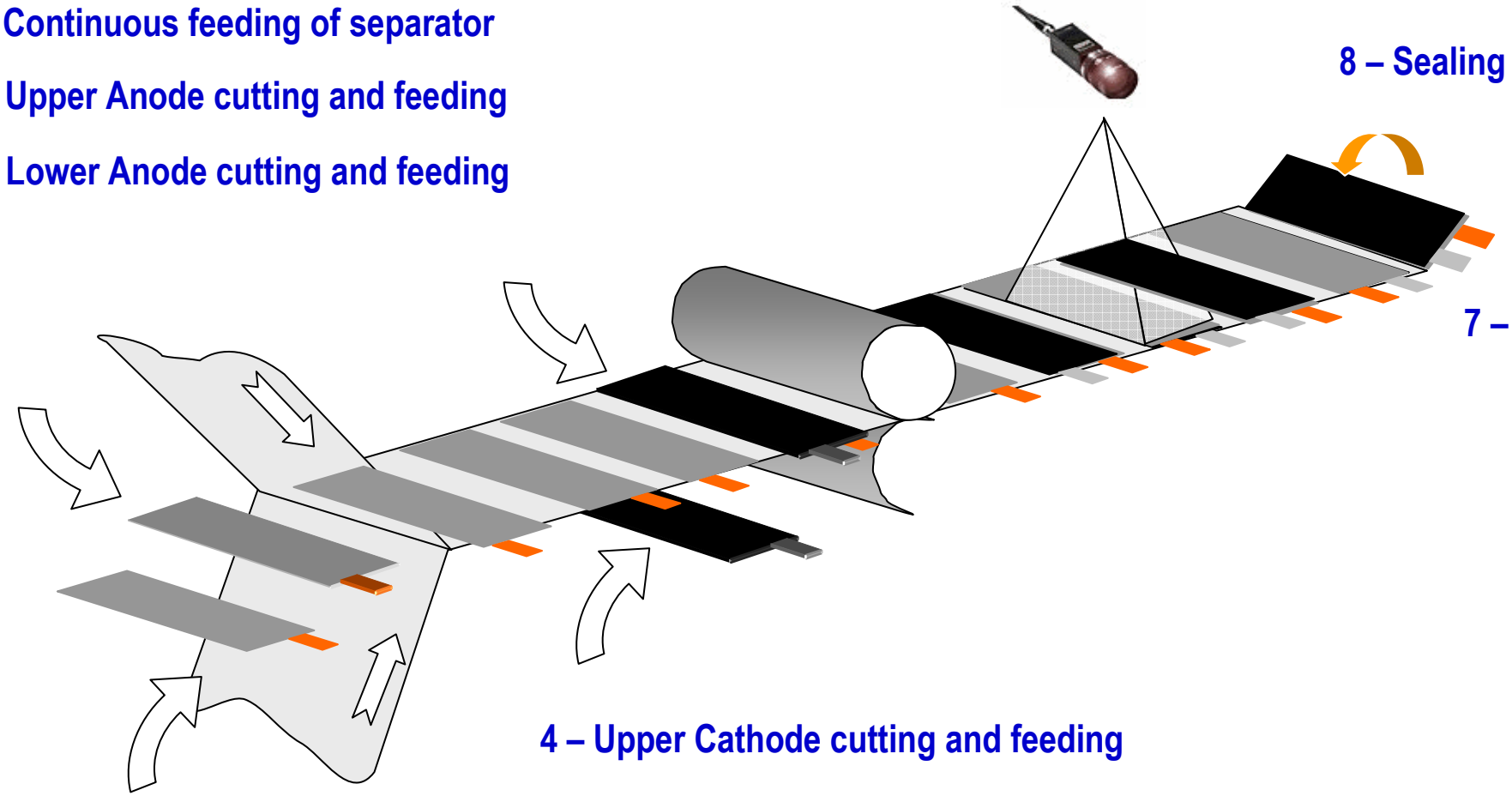
1 – Continuous feeding of separator

2 – Upper Anode cutting and feeding

3 – Lower Anode cutting and feeding

6 – in line SPC

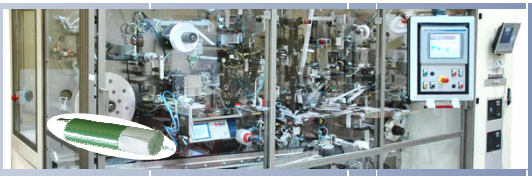
8 – Sealing & Extraction



7 – Winding

4 – Upper Cathode cutting and feeding

5 – Lower Cathode cutting and feeding



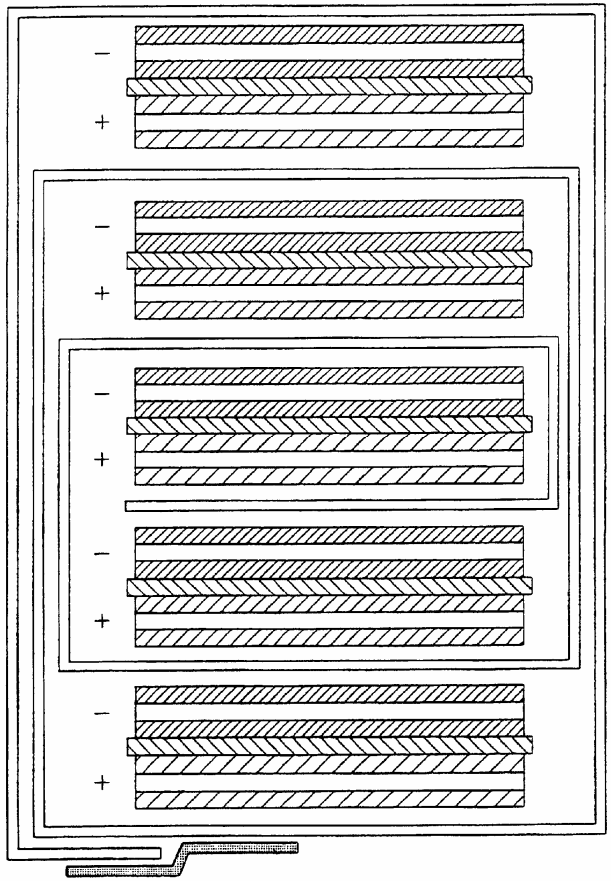
And the result is…

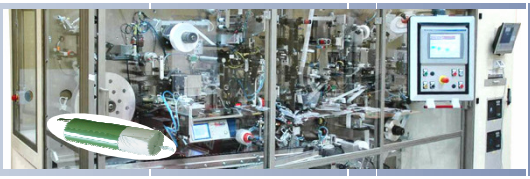
- *A stacked electrode construction*
- *A continuous process method*

Benefits include…

- *Self supporting structure*
- *Reduction of wrinkling*
- *Enhanced safety*

Let's take a closer look

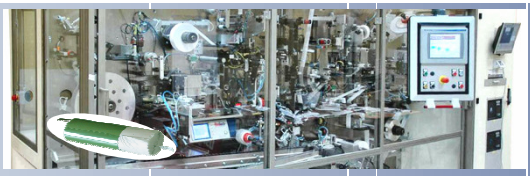




Cell Assembly

Electrode Insertion

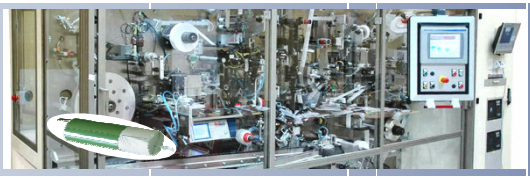
Feeding 1/3X material width

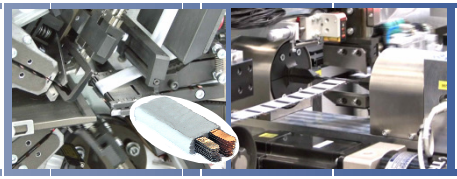


Cell Assembly

Strip Lamination

Continuous Flow Processing

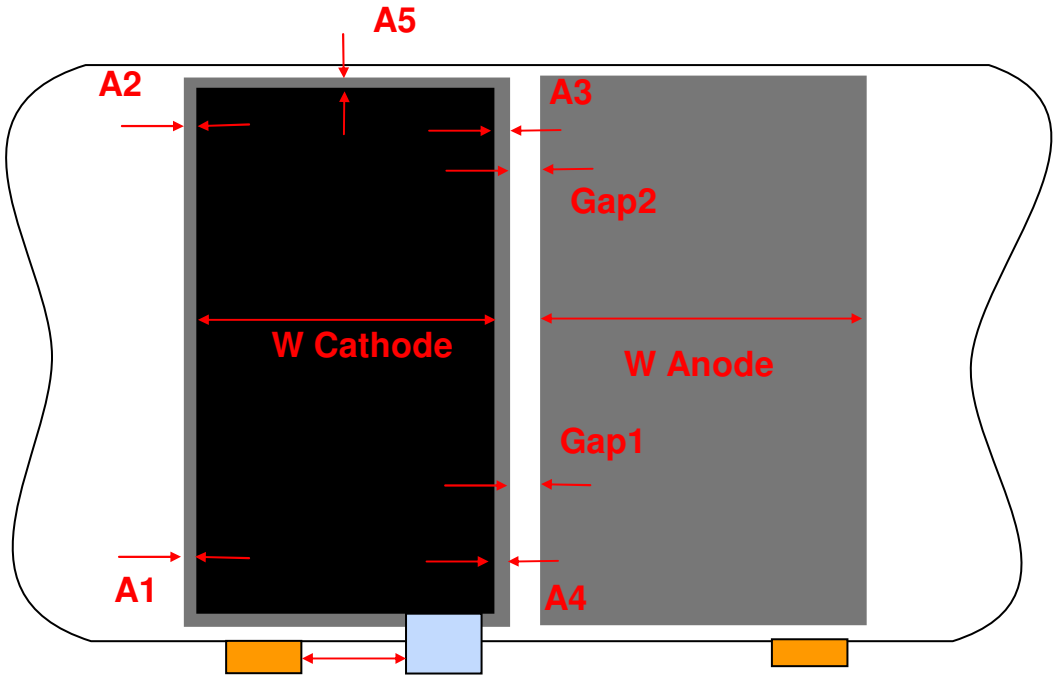




What can be monitored, analyzed, or recorded?

Each electrode is monitored for:

- Width
- Anode tab to Cathode tab placement
- Anode to Cathode side alignment
- Anode to Cathode top alignment
- Distance betweeen each Anode/Cathode pair

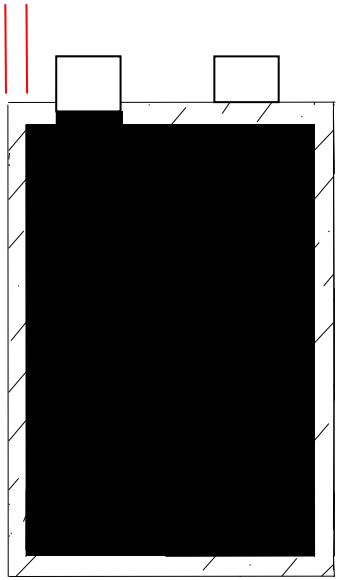


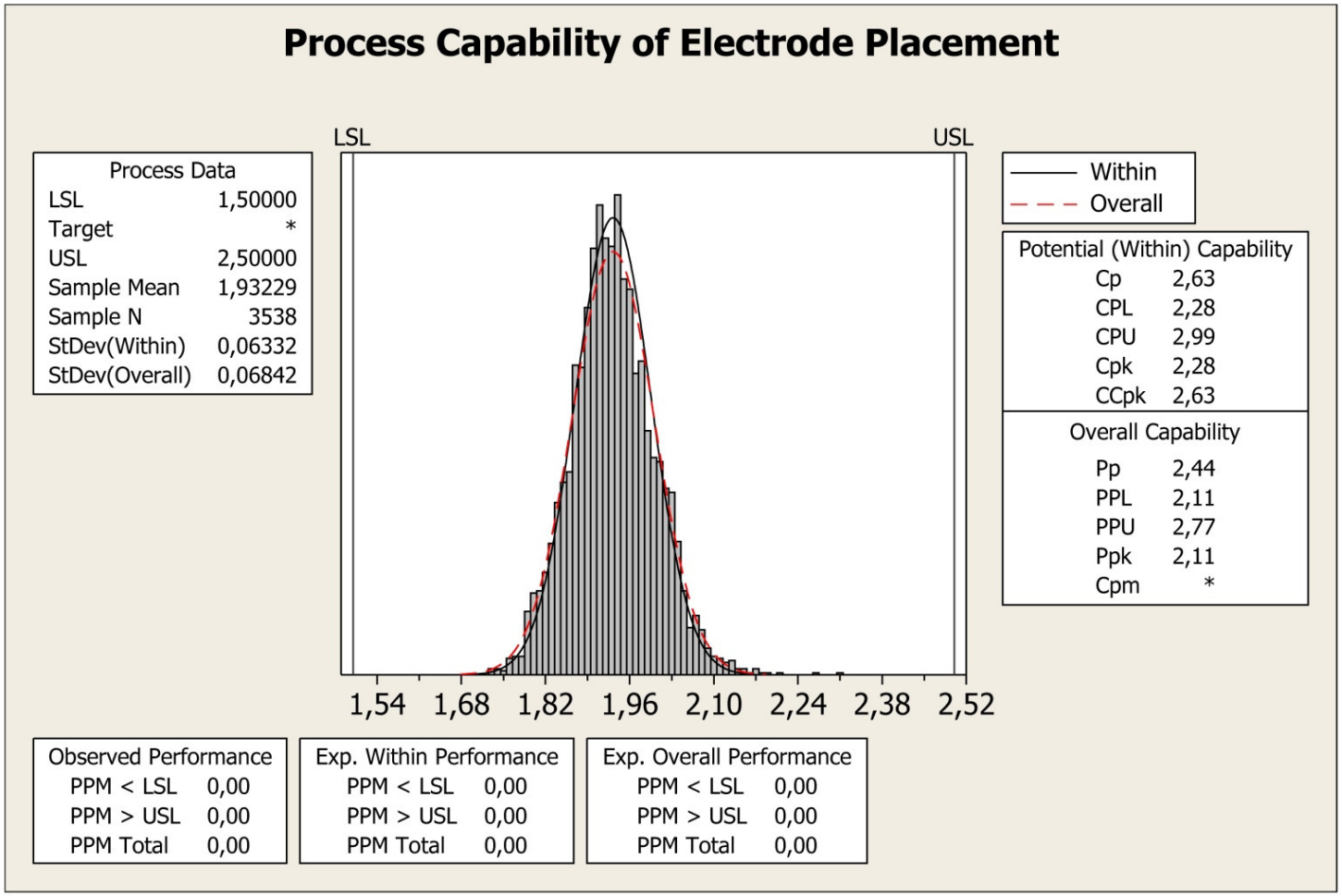
100% data collection for analysis on every electrode within the battery cell

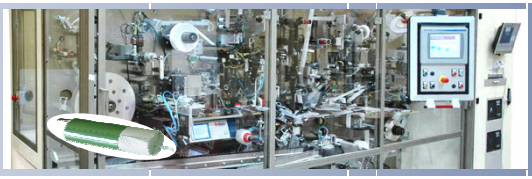
Record can be maintained visually for verification

What are typical results achieved?

Electrode edge

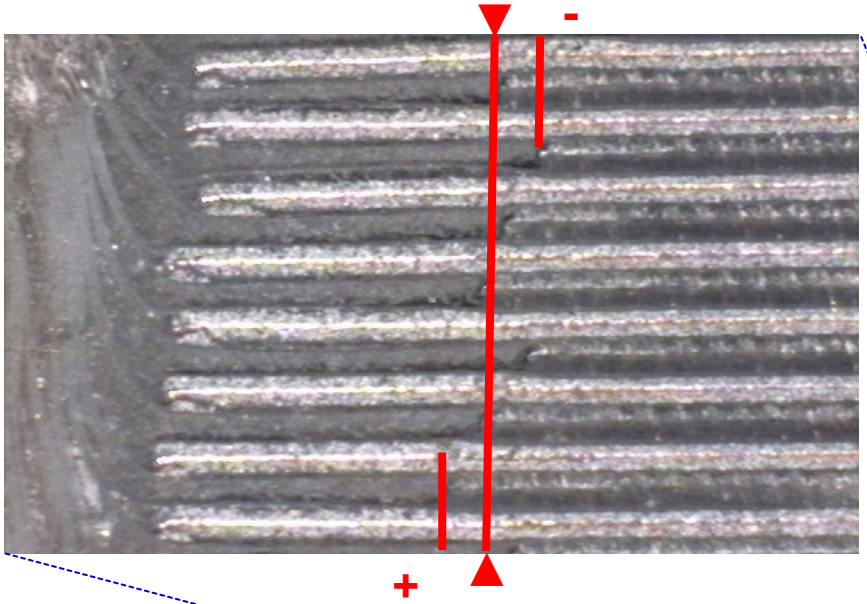


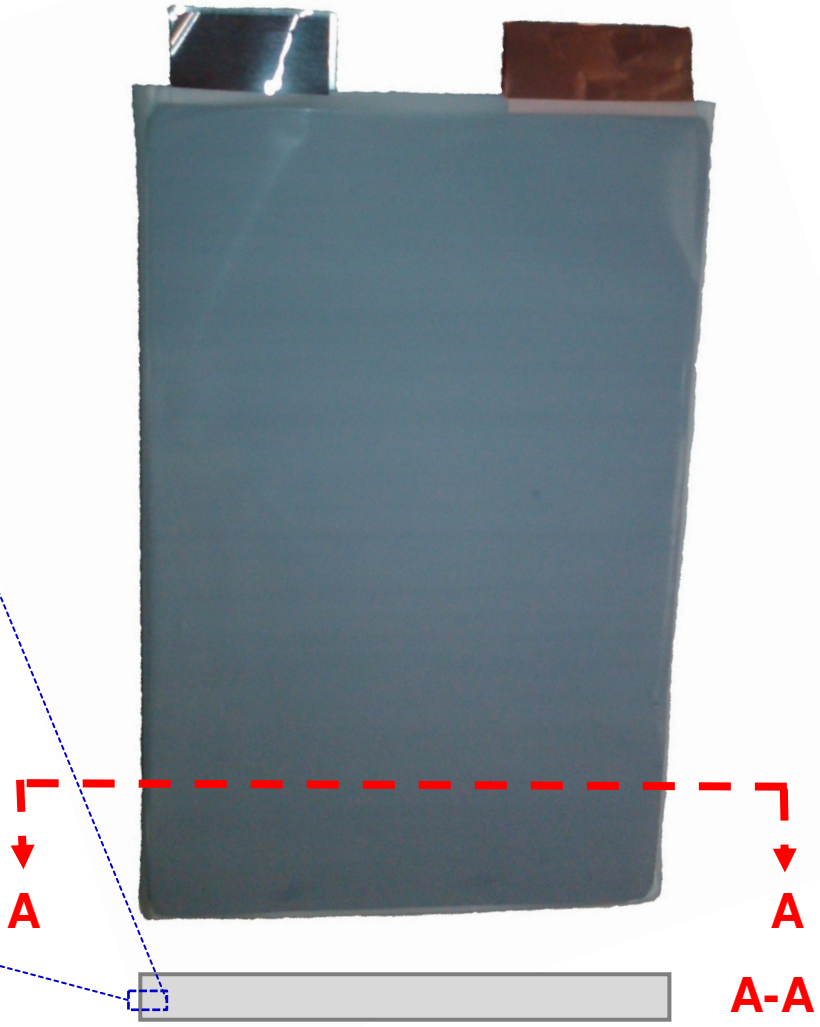




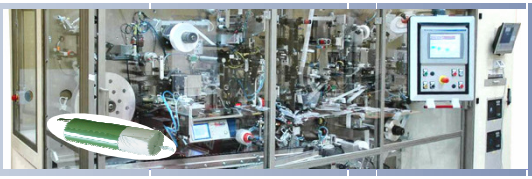
Inspection analysis

Cross section: 40 x magnification



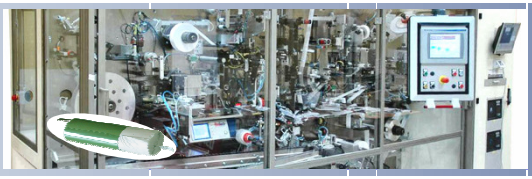


Overall positional tolerance ~ ±0.3 mm



Summary of Key Parameters (Large Format Batteries)

Process	Tolerance (+/-)	LSL (mm)	USL (mm)	STD (mm)	CpK
Anode tab to Cathode tab	0.5	45.00	46.00	0.06	> 2.0
Anode/Cathode (sides)	0.5	3.00	4.00	0.08	> 2.0
Anode/Cathode (bottom)	0.5	1.50	2.50	0.08	> 2.0
Gaps (representative)	0.5	2.50	3.50	0.08	> 2.0

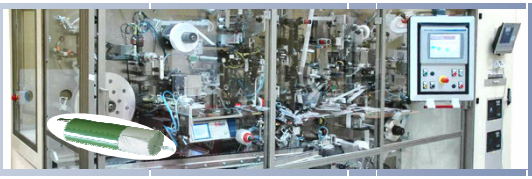


Summary of Processes

Assembly Method	Material Feeding			Quality	Safety
	Method	mm/sec	Ahr/min	Position	Integrity
Winding	Cont.	500 – 1000	300	+	+
Stacking	Index	50 – 75	20	-	-
Prismatic Winding	Cont.	250 – 300	120	+	-
Z – Folding	Index	75 – 100	40	-	-
Stack Winding	Cont.	250 – 300	120	+	+

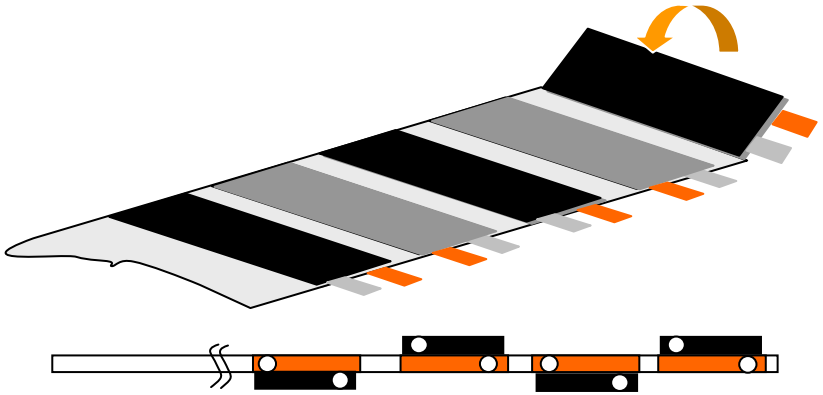
Assumes h = 250 mm

Stack Winding achieves the goals of throughput and quality.



An Innovative Solution – Stack Winding

Stack Winding	Improved manufacturing throughput compared to Z – Folding and Stacking
	Utilize same packaging as Stacking
	Same packaging density as Stacking
Process	Continuous material feeding



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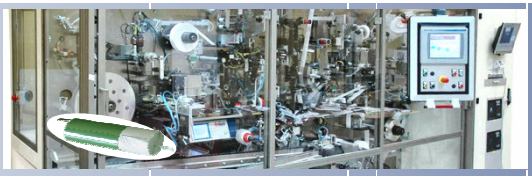

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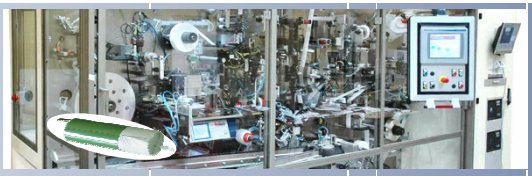
Example Product **20 Ahr**

73 Wh

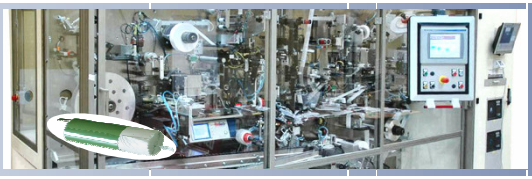
Base Cell BOM Structure						Optional
Item	**Description**	**unit**	**$/unit**	**qty/unit**	**cost**	**% annual change**
1	Cathode	m2	30,00	0,500	$15,00	-5%
2	Anode	m2	15,00	0,500	$7,50	-5%
3	Separator	m2	2,50	0,500	$1,25	-2%
4	Electrolyte	kg	18,00	0,160	$2,88	-3%
5	Lead tab A (w/adhesive)	each	0,40	1,000	$0,40	
6	Lead tab B (w/adhesive)	each	0,40	1,000	$0,40	
7	Packaging, Al/PP laminate	m^2	2,00	0,450	$0,90	-4%

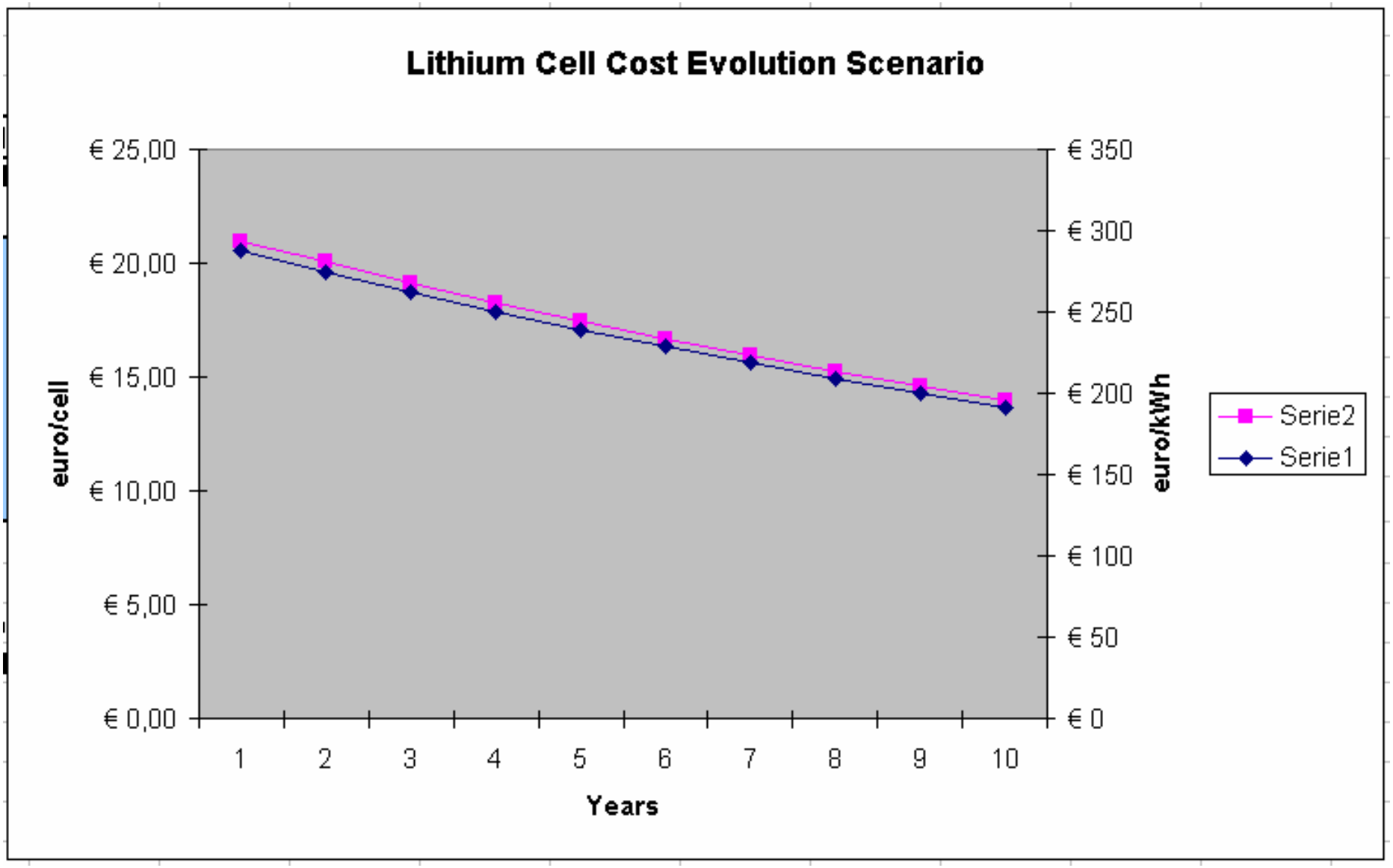
Year 1 Cost Roll Up **$28,33**

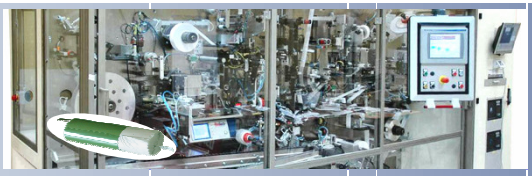


Common Facility Assumptions for Battery Plant			
Factory utilization	24	hr/day	
	6	day/week	
	40	weeks	

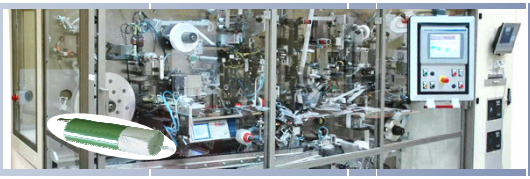
COGS Summary (Option 1)											
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Material	€/cell	21,413	20,452	19,536	18,664	17,833	17,042	16,289	15,571	14,888	14,237
Direct Labor	€/cell	0,265	0,272	0,281	0,289	0,298	0,307	0,316	0,325	0,335	0,345
Indirect	€/cell	0,794	0,833	0,833	0,833	0,833	0,833	0,833	0,833	0,833	0,833
Depreciation	€/cell	0,194	0,262	0,262	0,262	0,262	0,262	0,262	0,262	0,262	0,262
COGS	€/cell	22,665	21,819	20,912	20,048	19,226	18,444	17,700	16,992	16,318	15,677
ASP	€/cell	37,04	35,19	33,43	31,75	30,17	28,66	27,23	25,86	24,57	23,34
Gross Margin	%	39	38	37	37	36	36	35	34	34	33

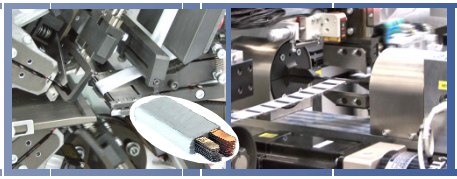



Lithium Cell Cost Evolution Scenario
€ 25,00
€ 20,00
€ 15,00
€ 10,00
€ 5,00
€ 0,00
euro/cell
€ 350
€ 300
€ 250
€ 200
€ 150
€ 100
€ 50
€ 0
euro/kWh
1
2
3
4
5
6
7
8
9
10
Years
Serie2
Serie1



Thanks for Your attention



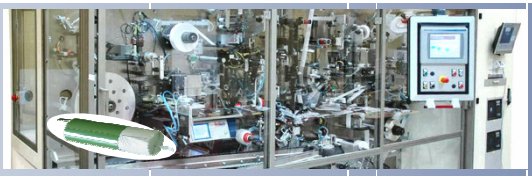


Corporate Statistics

Headquarters:	Simpsonville, SC
Manufacturing:	23 facilities worldwide
Square feet:	3 million
Employees:	10,000
Revenue:	~$800 million

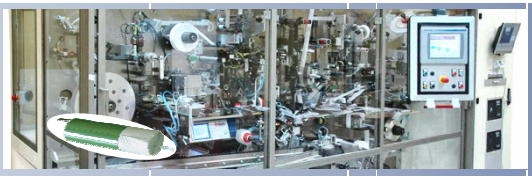
Arcotronics Industries (Machinery) Statistics

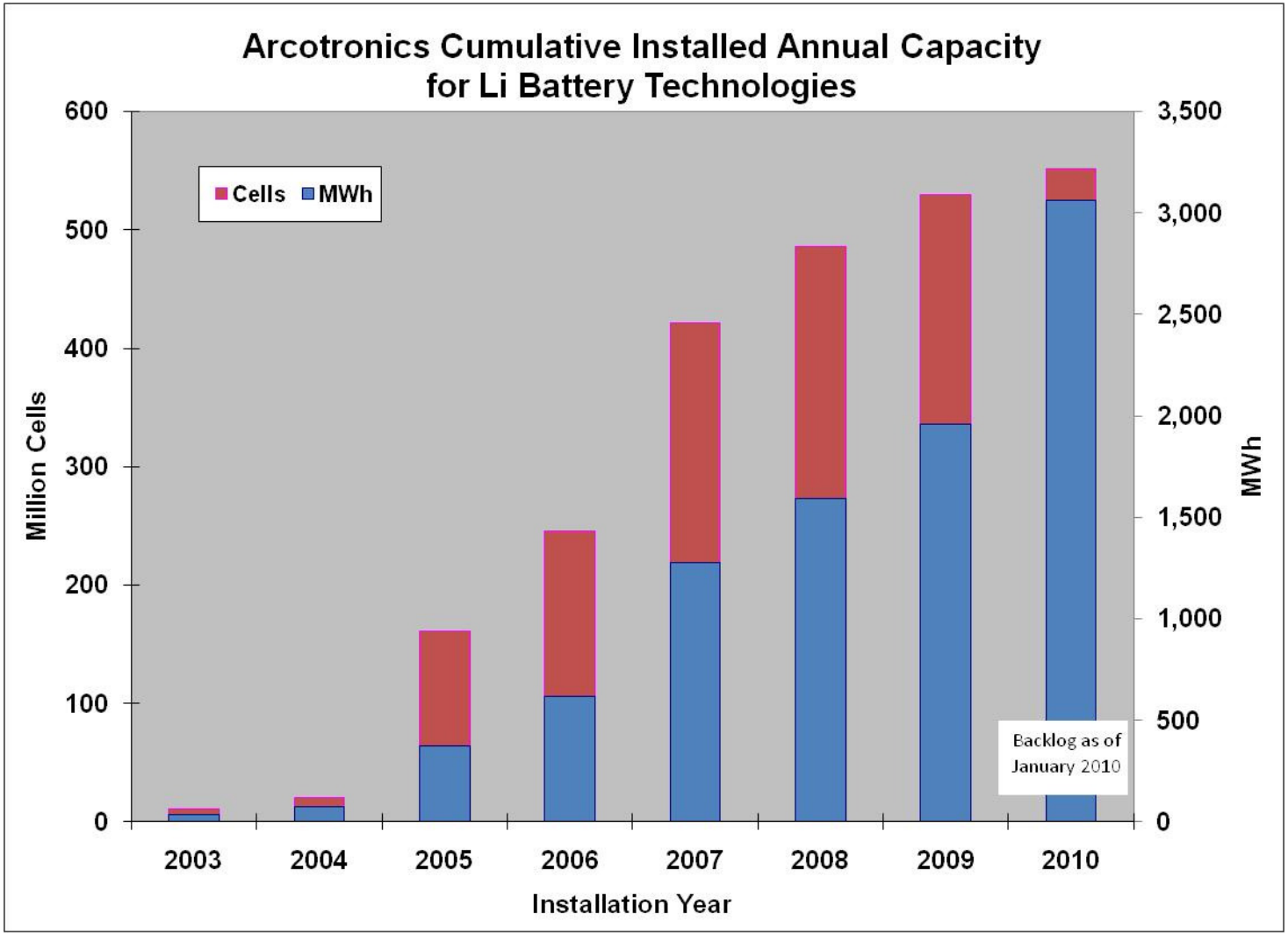
Headquarters:	Sasso Marconi, Italy
Manufacturing:	Sasso Marconi, Italy
Square feet:	200,000
Employees:	~100



Arcotronics Industrial Experience

1962	Start of production for film capacitors
1972	Machinery Division established
1986	Entry into battery business industry supplying winding machines
1988	Develops equipment for cylindrical Lithium batteries
1992	Develops monocell & bi cell assembly methods (stacking)
1995	Bi cell lamination process developed (PVDF separators)
1997	Develops equipment for prismatic winding (consumer)
1998	Develops equipment for double layer supercapacitors
2001	Develops stack winding process
2004	First installation for HEV
2005	Highest speed winding system released, 18650 battery manufacturing




Arcotronics Cumulative Installed Annual Capacity
for Li Battery Technologies
Cells
MWh
Million Cells
MWh
600
500
400
300
200
100
0
3,500
3,000
2,500
2,000
1,500
1,000
500
0
2003
2004
2005
2006
2007
2008
2009
2010
Installation Year
Backlog as of
January 2010