Optimising Li-ion Cell Layers

Rapid Cell Design For EV Fast Charging

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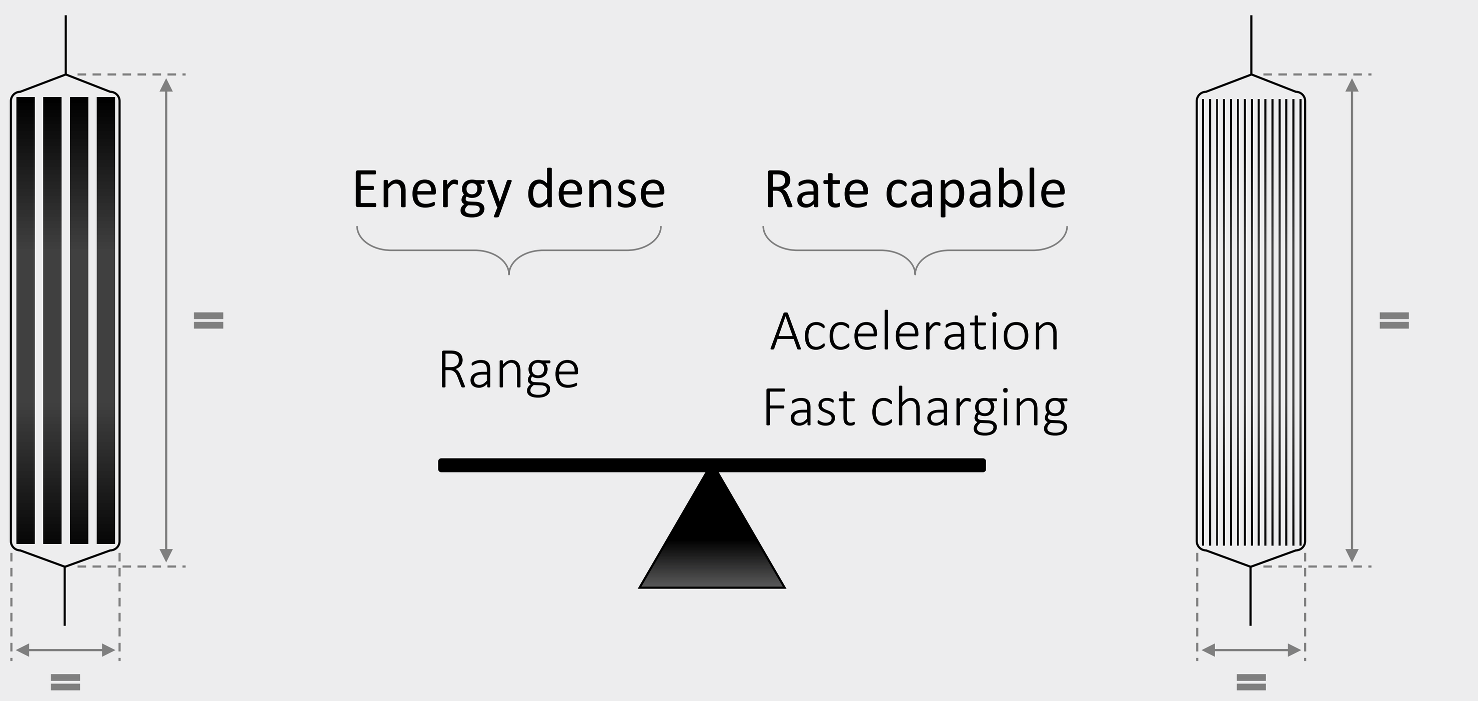

ENERGY & POWER BALANCE

- Conflicting requirements pose a layer optimisation problem
- Desire trading of energy & power in equally-dimensioned cells
- Layer reconfiguration trades fraction of active material mass with surface area available for redox reaction
- Empirical determination of optimal layer count is slow, costly & may not provide energy-density maximising result
- **We propose a rapid & inexpensive model-based alternative**

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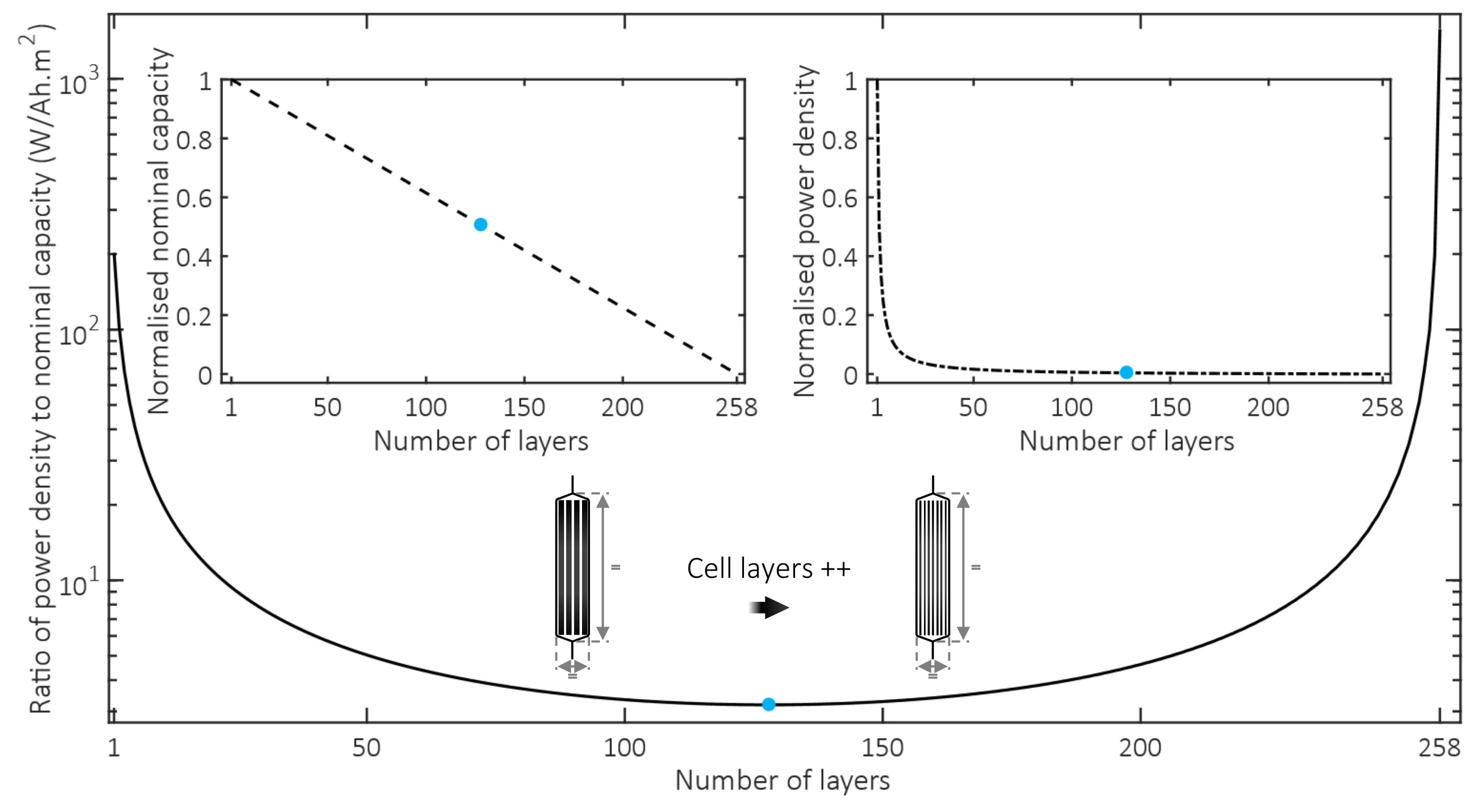
LAYER OPTIMISATION

- The optimal (i.e. range-maximising) layer configuration is the minimum number of layers that meets EV acceleration and fast charging targets
- Initially, we gain a lot of rate capability for little energy density loss since power density per layer decreases faster than cell nominal capacity
- At higher layer counts it becomes increasingly expensive, in terms of energy density sacrificed, to accommodate higher powers
- **Efficient designs employ < half the maximum possible number of layers**



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1 Define vehicle

xEV platform	PHEV
Powertrain	(series)
Module & cell configuration	8S1P (mod.) 12S1P (cells)
xEV mass (w/o cells)	1,654 kg (inc. ICE)
Fast charge SOC range	30 - 80 %

2 Define criteria

Fast charging	*Acceleration*
$T(t) < T_{max}$	$T(t_f) < T_{max}$
$V(t) < V_{max}$	$V(t_f) > V_{min}$
$z(t) \geq z^*$	$z(t_f) > z_{min}$
$C_s^*(t) < C_{s_{sat}}$	
$t < t_{max}$	

Li-PLATING PROTECTED FAST CHARGE

- Specify desired xEV configuration & define performance criteria
- Cells undergo simulated vehicle acceleration & fast charging
- Charge time is minimised with a constant power strategy
- **Design for highest powers & impose an Li concentration limit**
- **Cell designs exhibit Li-plating protection & max. energy density**

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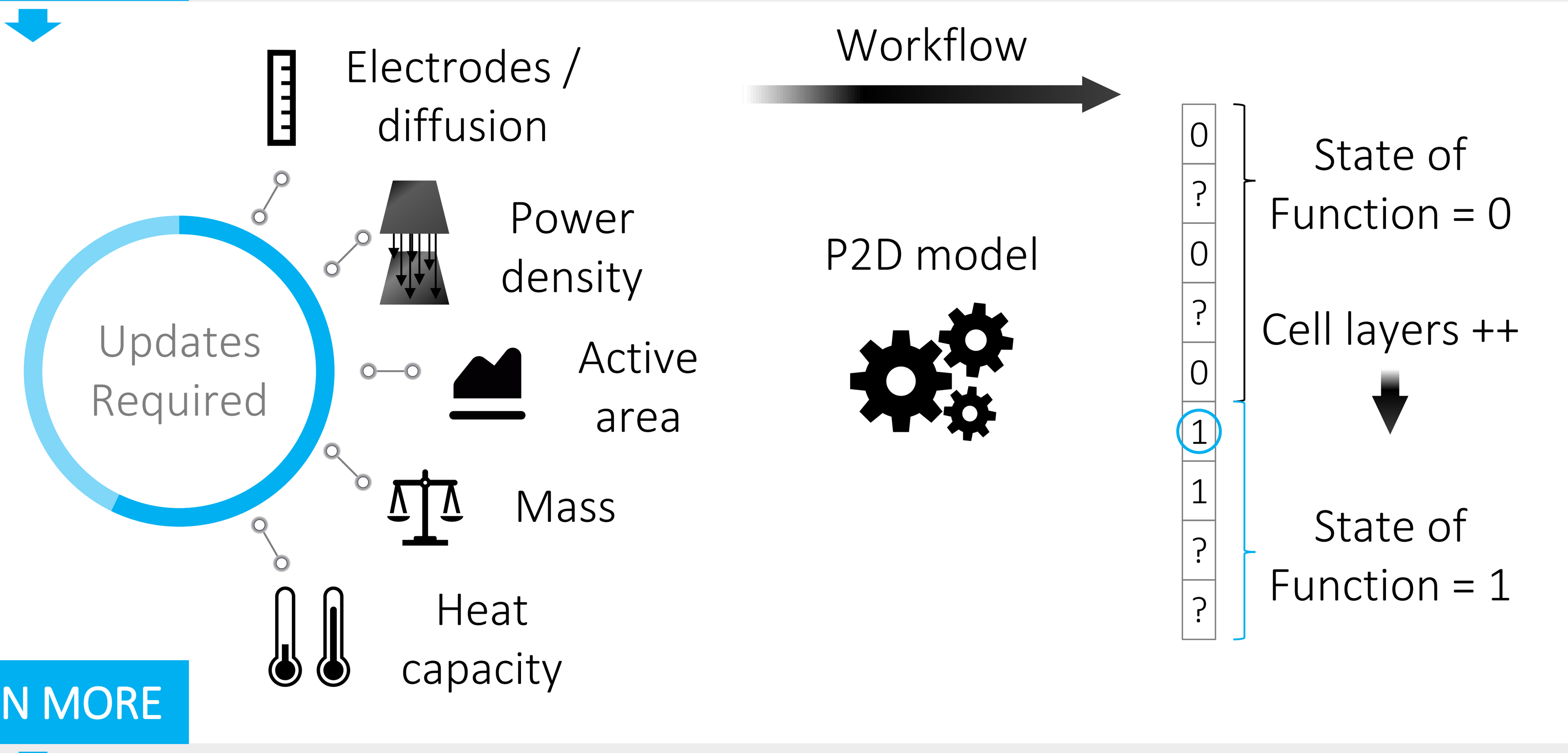
P2D SIMULATION

- Custom binary search & open-source electrochemical P2D model capable of directly accepting *power* inputs
- Efficiently screen layer configurations, identifying optimal value
- Each new layer configuration requires updated electrode thicknesses, active surface area, cell mass and heat capacity
- Vector of layer State-of-Functions is produced; lowest layer count with a unity SoF is the optimal



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PHEV Charging Power: 50 kW

Coolant temp., T_{sink} (°C) \ Initial cell temperature, T_{init} (°C)	15	20	25	30	35	38
5	110	106	104	101	99	98
10	107	104	101	99	97	96
15	105	102	99	97	95	94
20	103	100	98	96	94	93
25	100	98	96	94	92	91
30	99	96	94	92	91	90
35	97	95	93	91	89	88
38	96	94	92	90	88	88
40	95	93	91	89	88	87
45	93	91	90	88	87	86
49	92	90	89	87	86	85

PHEV Charging Power: 80 kW

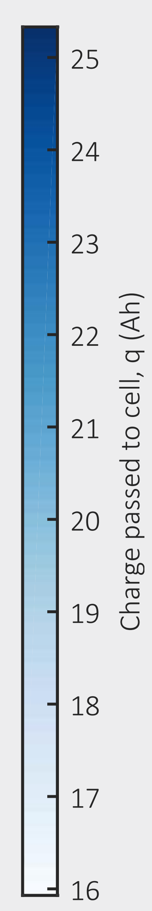
Coolant temp., T_{sink} (°C) \ Initial cell temperature, T_{init} (°C)	15	20	25	30	35	38
5	127	123	119	116	113	112
10	125	121	118	115	112	110
15	124	120	116	113	111	109
20	122	118	115	112	110	108
25	121	117	114	111	109	107
30	119	116	113	110	107	106
35	118	114	111	109	106	105
38	117	114	111	108	106	105
40	117	113	110	108	105	104
45	115	112	109	107	104	103
49	114	111	108	106	104	103

PHEV Charging Power: 110 kW

Coolant temp., T_{sink} (°C) \ Initial cell temperature, T_{init} (°C)	15	20	25	30	35	38
5	140	135	131	127	124	122
10	139	134	130	126	123	121
15	138	133	129	125	122	120
20	136	132	128	124	121	120
25	135	131	127	124	120	119
30	134	130	126	123	120	118
35	133	129	125	122	119	117
38	133	128	125	121	119	117
40	132	128	124	121	118	117
45	131	127	123	120	117	116
49	131	126	123	120	117	125

PHEV Charging Power: 135 kW

Coolant temp., T_{sink} (°C) \ Initial cell temperature, T_{init} (°C)	15	20	25	30	35	38
5	150	144	139	135	132	130
10	149	143	139	135	131	129
15	148	143	138	134	131	129
20	148	142	137	133	130	128
25	147	141	137	133	129	127
30	146	141	136	132	129	127
35	146	140	135	132	128	126
38	145	140	135	131	128	126
40	146	140	135	131	128	126
45	144	139	134	131	127	127
49	145	139	134	130	127	



TAILORED CELL DESIGN MAPS

- Repeat for new ambient & cell temperatures to generate cell design maps precisely tailored to vehicle fast charge targets
- Values in coloured cells are optimal layer configurations
- Map colour is usable capacity; charge added, 30 – 80 % SOC window
- Black colours indicate unsuitable cell materials & thermal management system for specified temperatures & design targets
- Faster & lower cost than iterative, empirical development
- **Method can offer xEV range extension over empirical cell design**
- **Enables common module design for xEV platforms, lowering R&D costs & time to market for automotive OEMs**