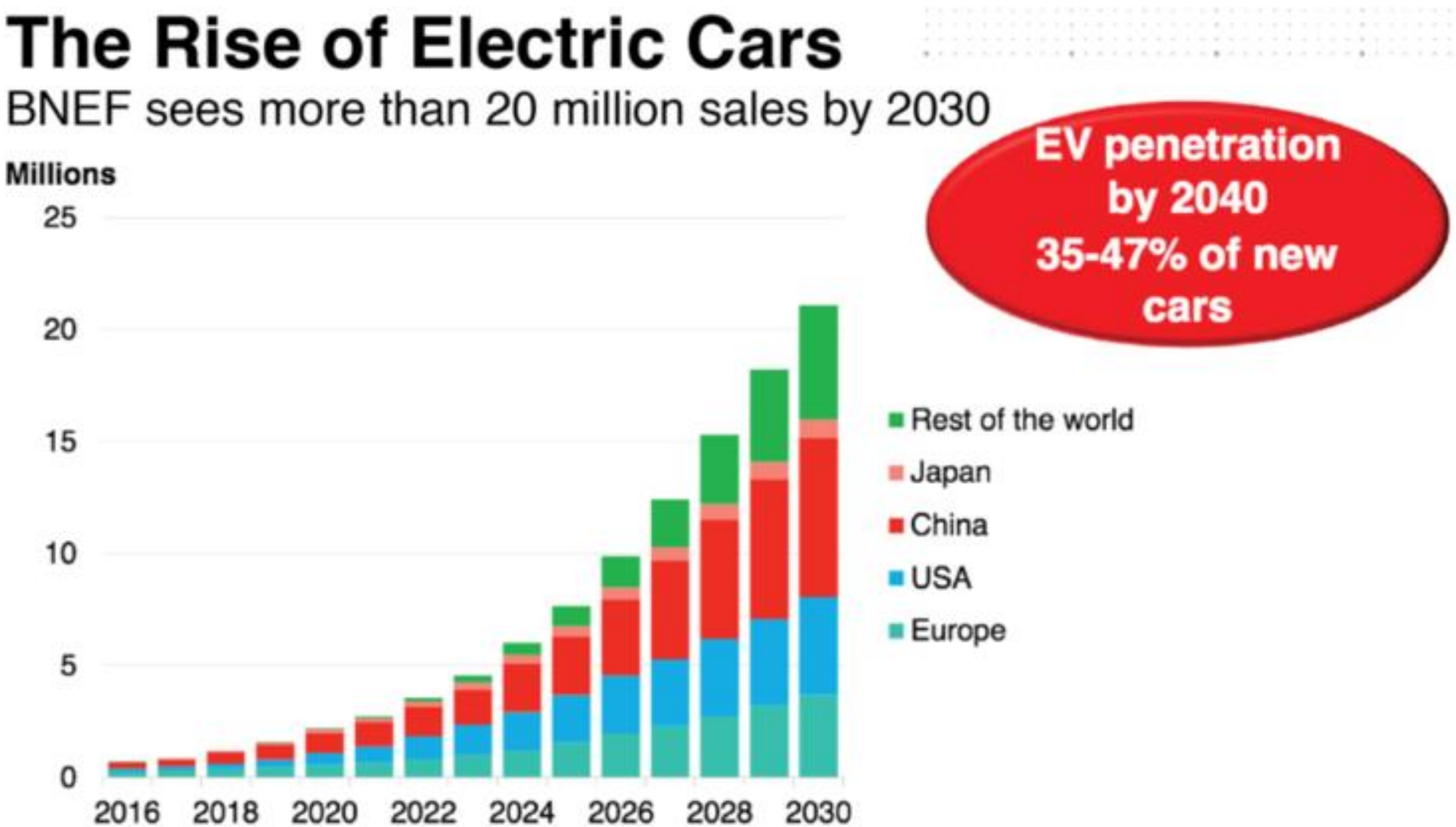
Energeia Labs
Power battery pack enclosure integrated with liquid cooling solution

Energeia Labs
恩能吉尔实验室

2018-7-30

Feng GuoAn



In 2016, the sales of EVs in the world reached 720,000, and in 2017 was about 1,160,000, with 61% increase. Among this, China sales 570,000, accounting for half the share.

Safety

Performance

Reliability

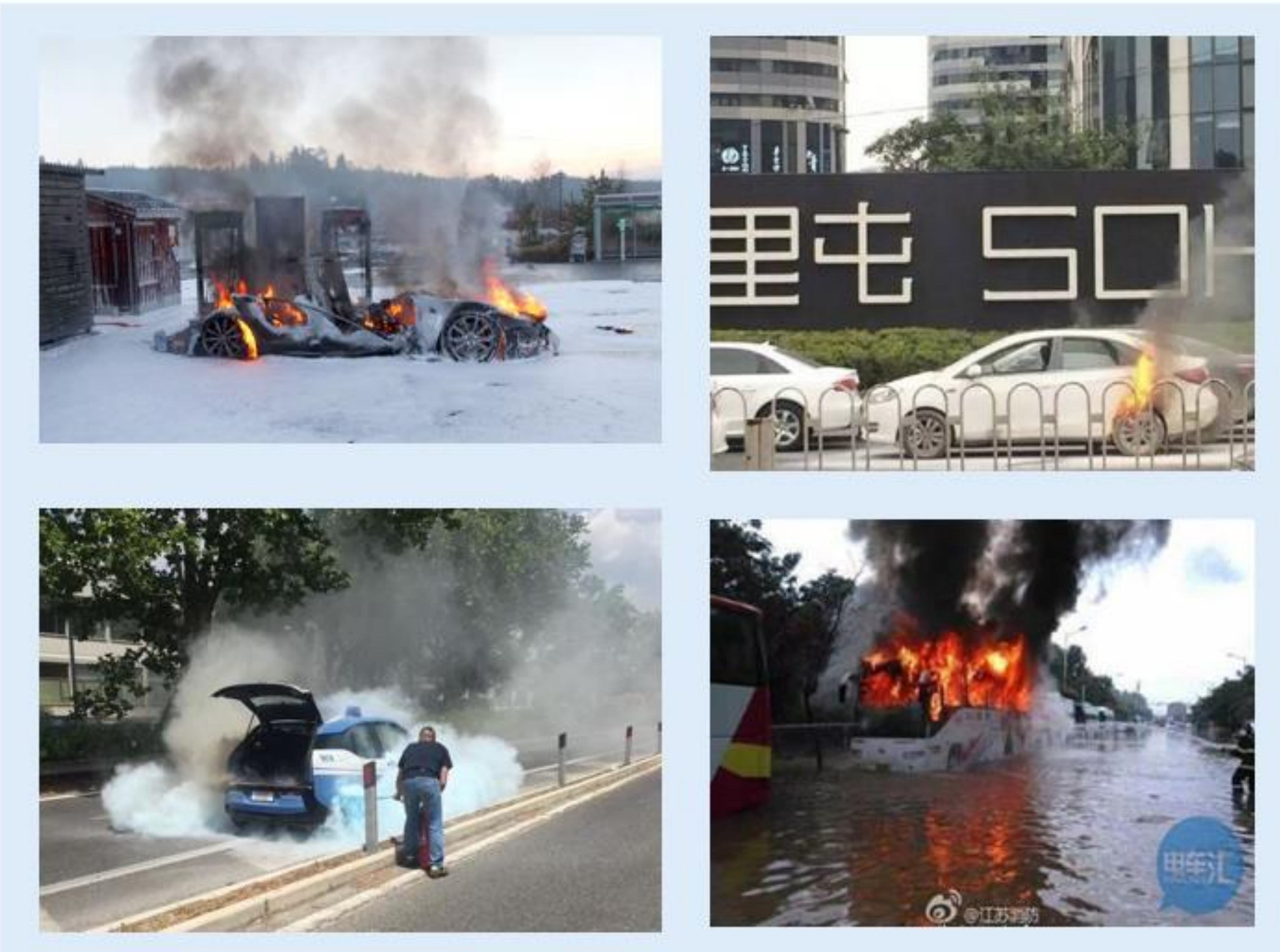
Temperature

Tesla, while charging
January 2016
Norway

JAC, spontaneous combustion
June 2016
Beijing, China

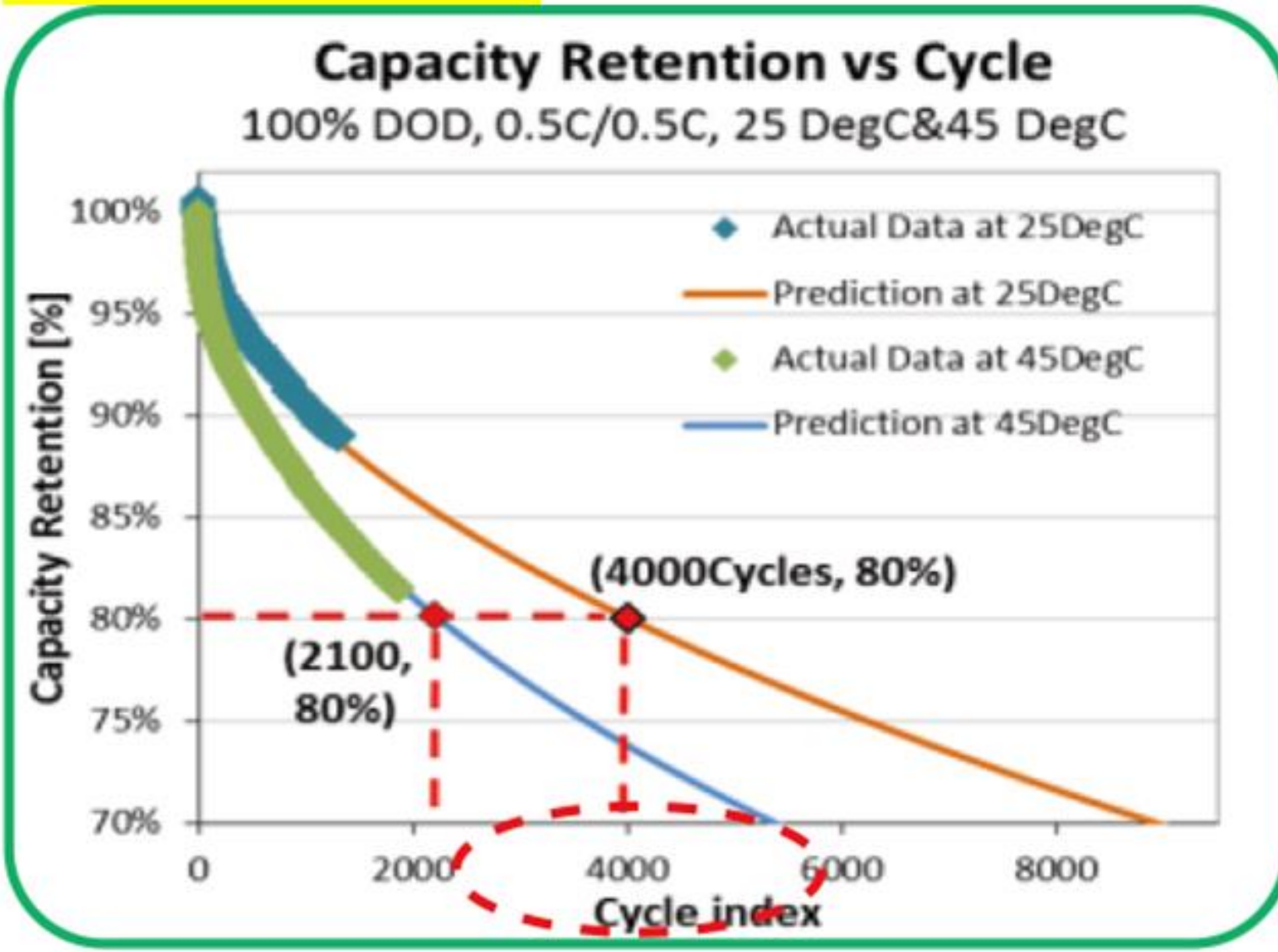
BMW, while in use
Summer 2016
Rome, Italy

Electric bus, driving over floodwaters
Nanjing, China



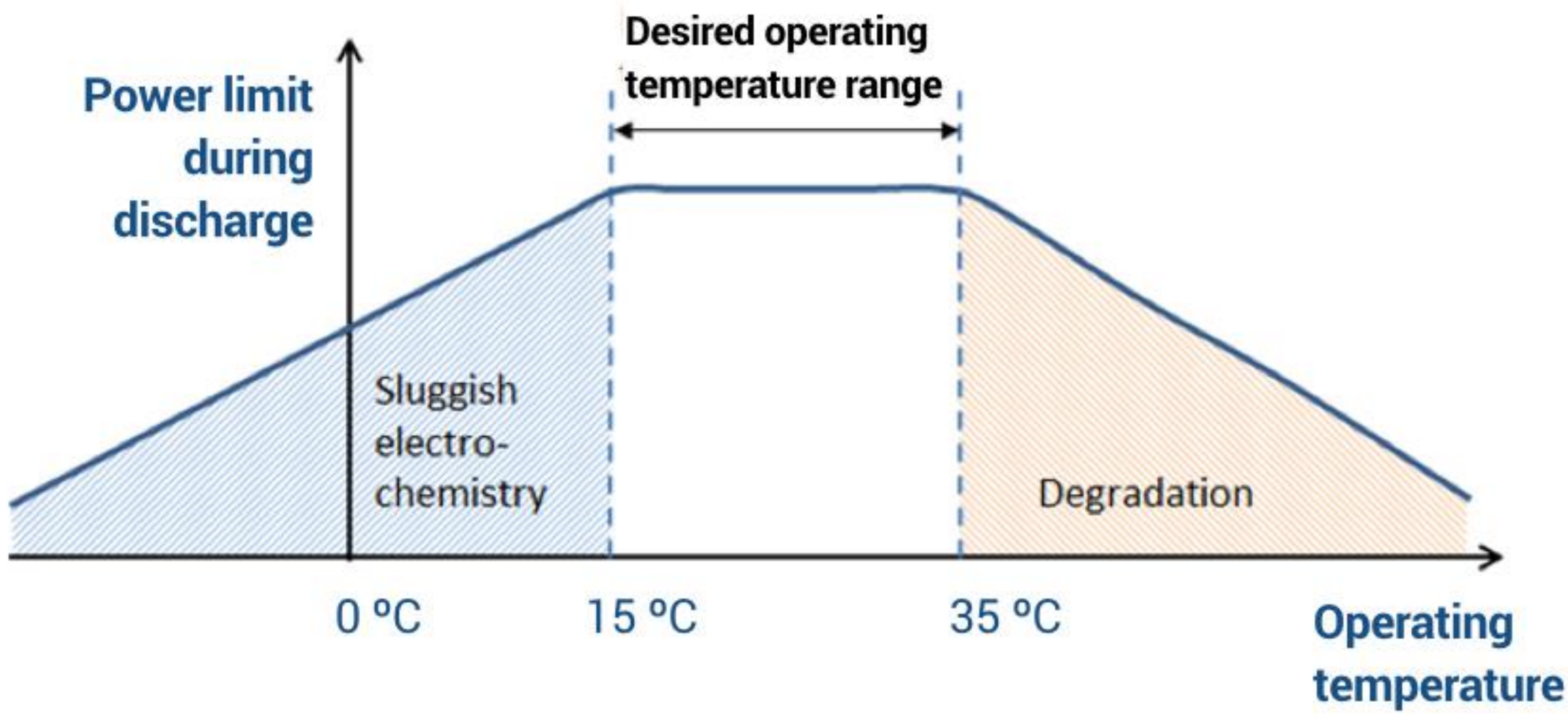
Common culprit:
mostly the battery

Temperature affects battery pack capacity and service life



From Yutong

Battery pack temperature requirements



Case study #1

EiG study (Korea)

Cell: 20Ah, 3.7V, $LiNiCoMn_2O_2$

Ambient temperature = 20°C

Discharging below 2C

Air cooling able to keep cell temperature < 55ºC

Discharging above 2C

Liquid cooling is needed

Case study #2

BB-2590

Widely used in US military

24 cells

Powers communication equipment

Single cell discharging at 1C (6A)

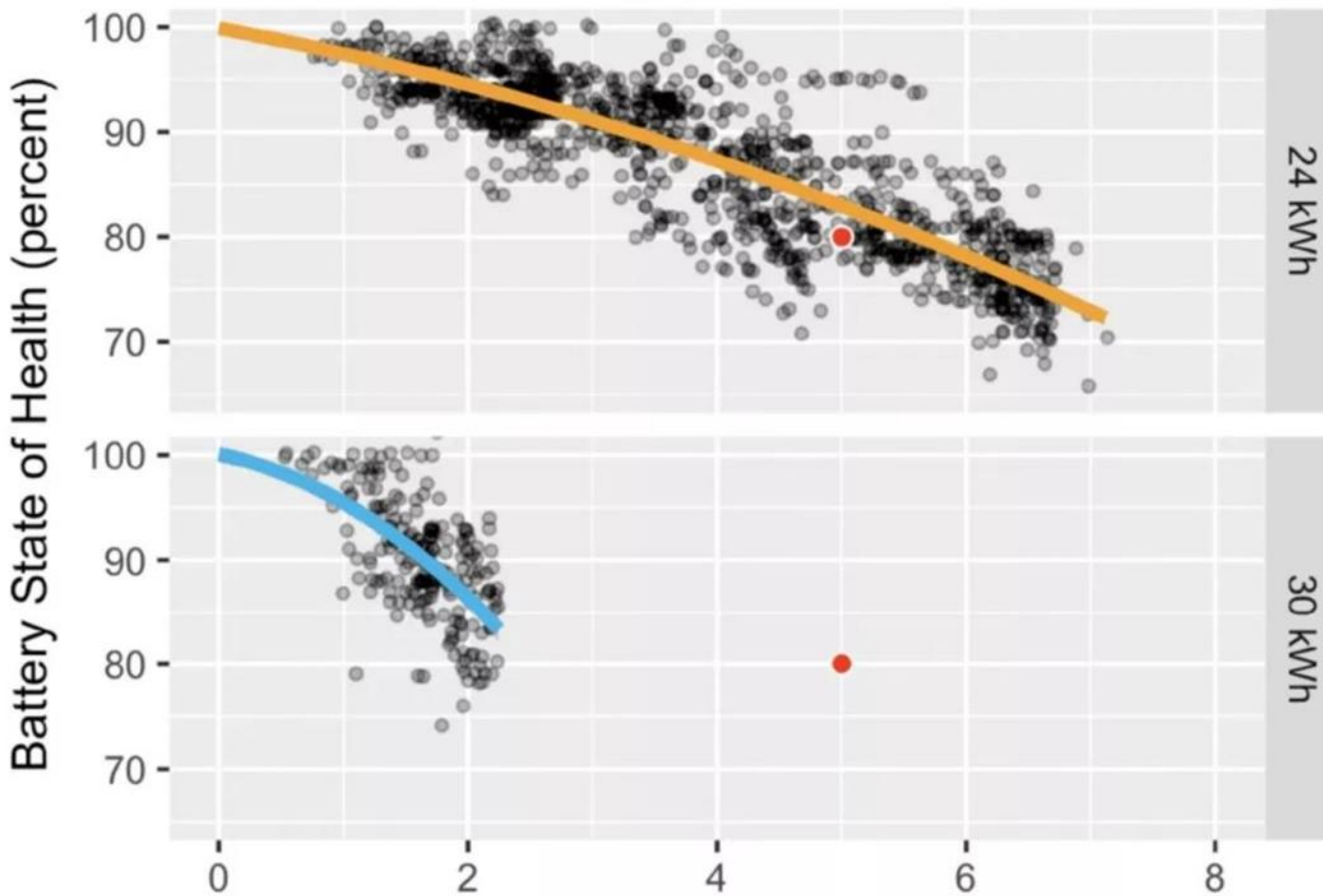
Will not exceed 45ºC

Internal temperature of pack discharging at 1C

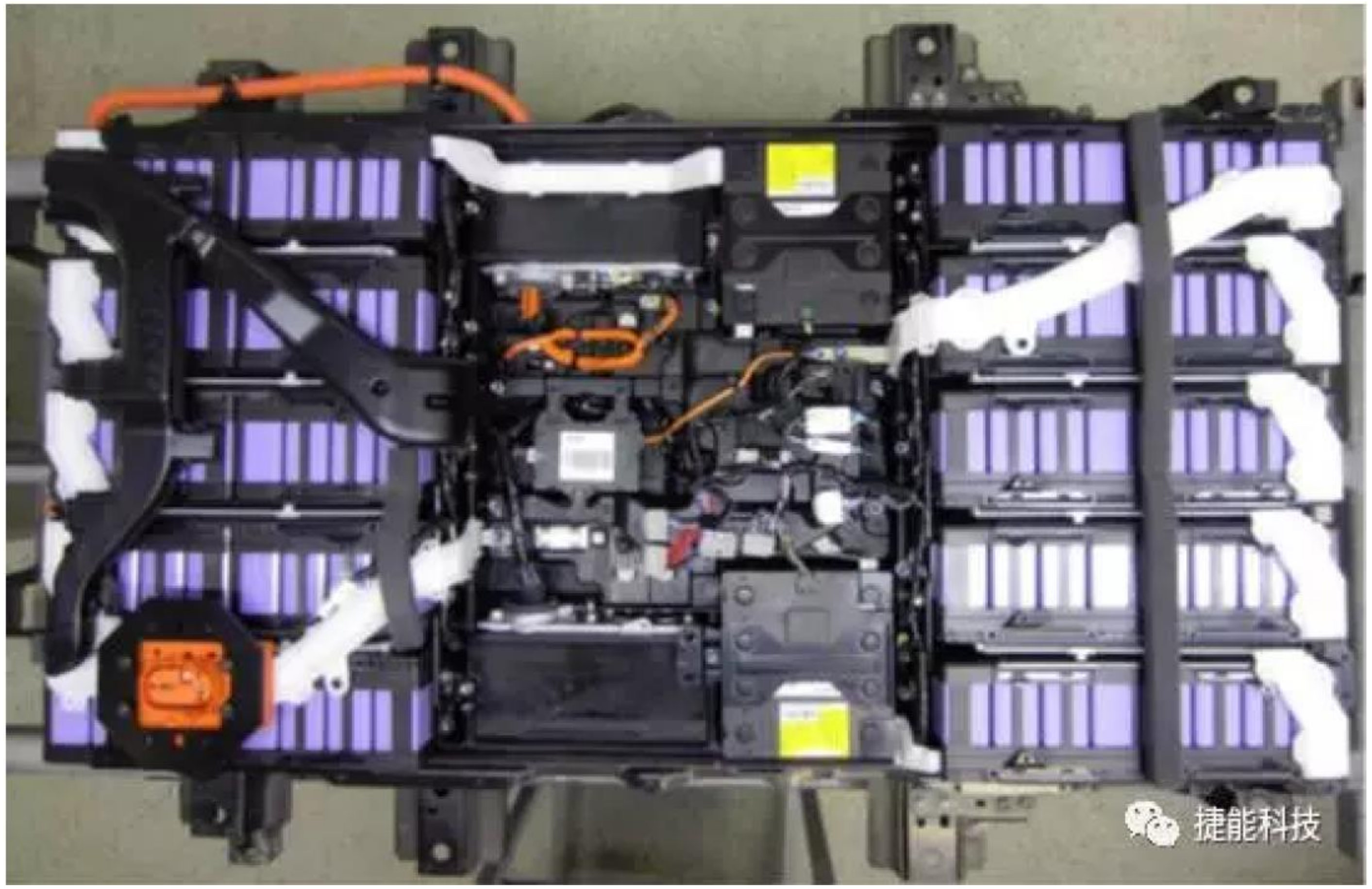
Can reach >70ºC

Nissan Leaf natural air-cooling

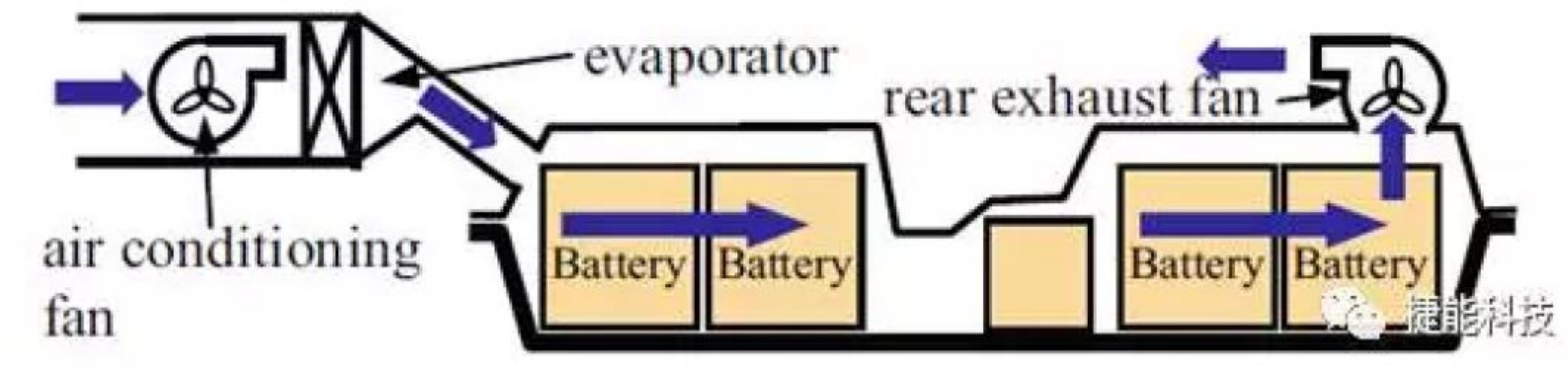
Deterioration at high temperature
Low cooling efficiency



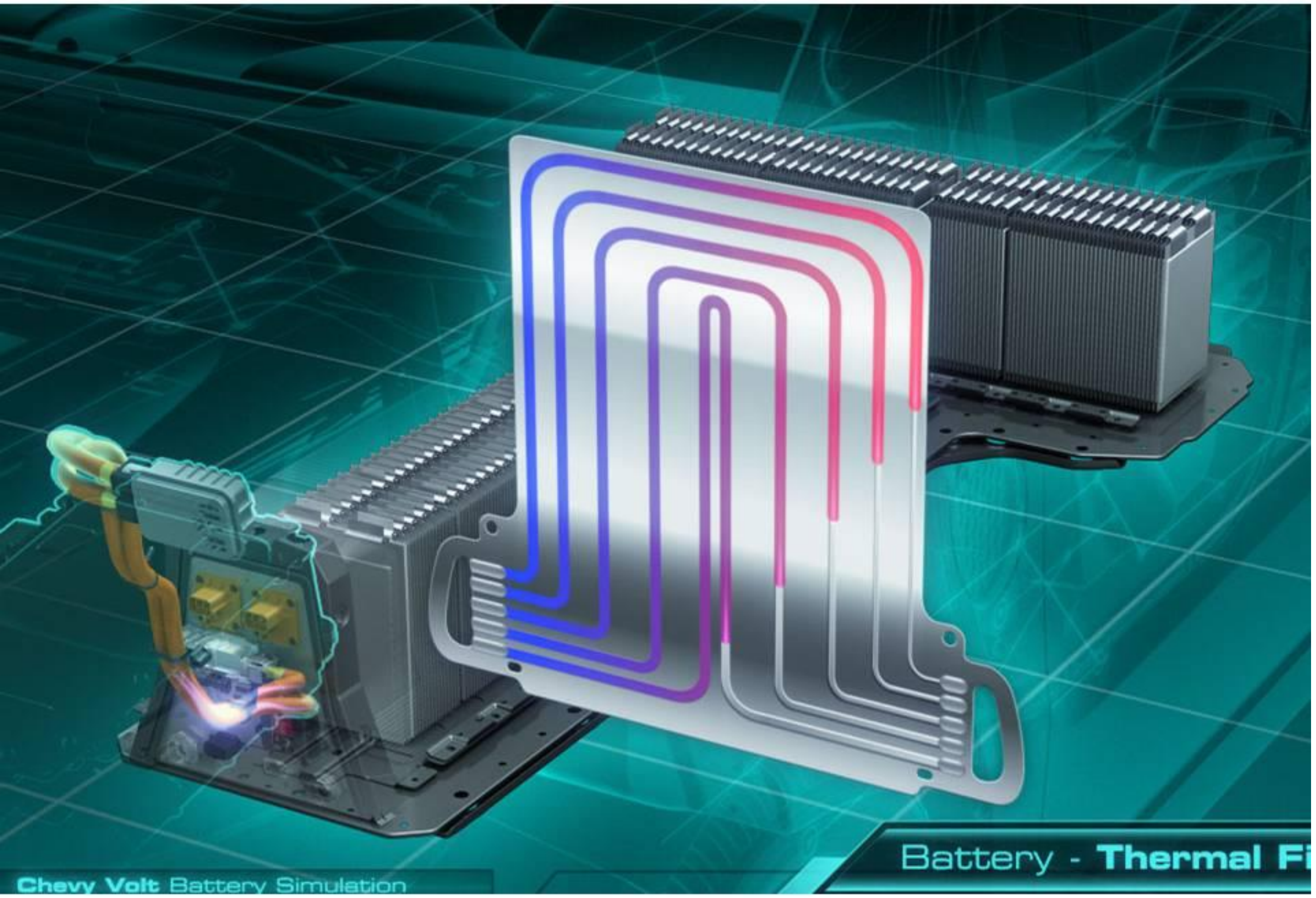
Mitsubishi i-Miev forced air-cooled



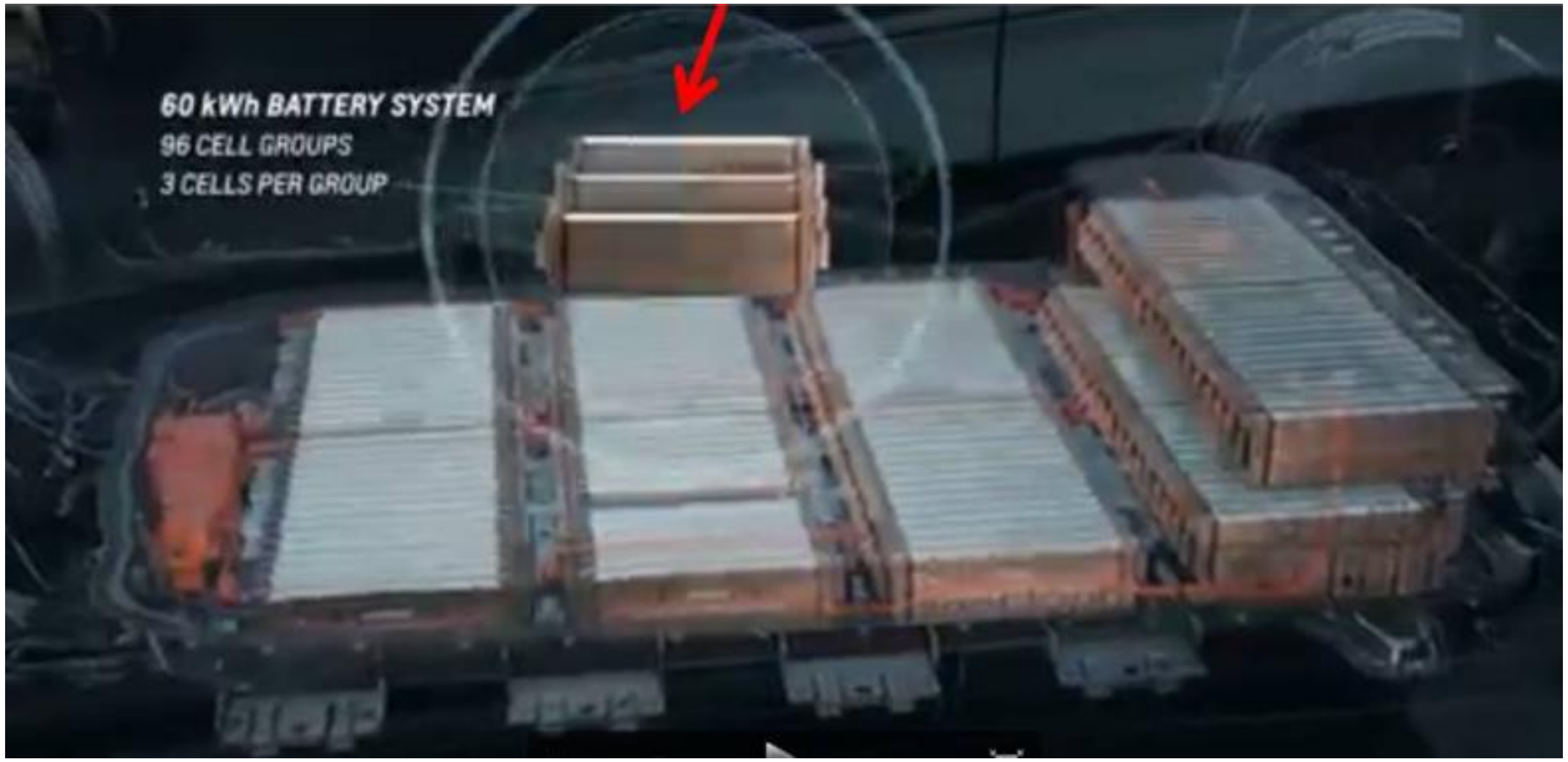
Intake / outlet vents,
Unable toachieve
IP67 sealing

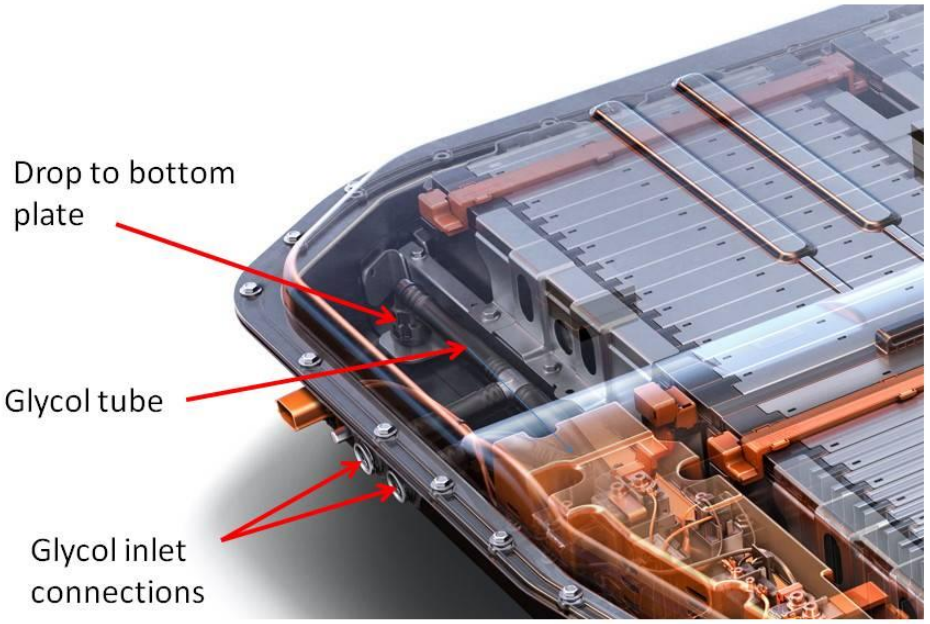


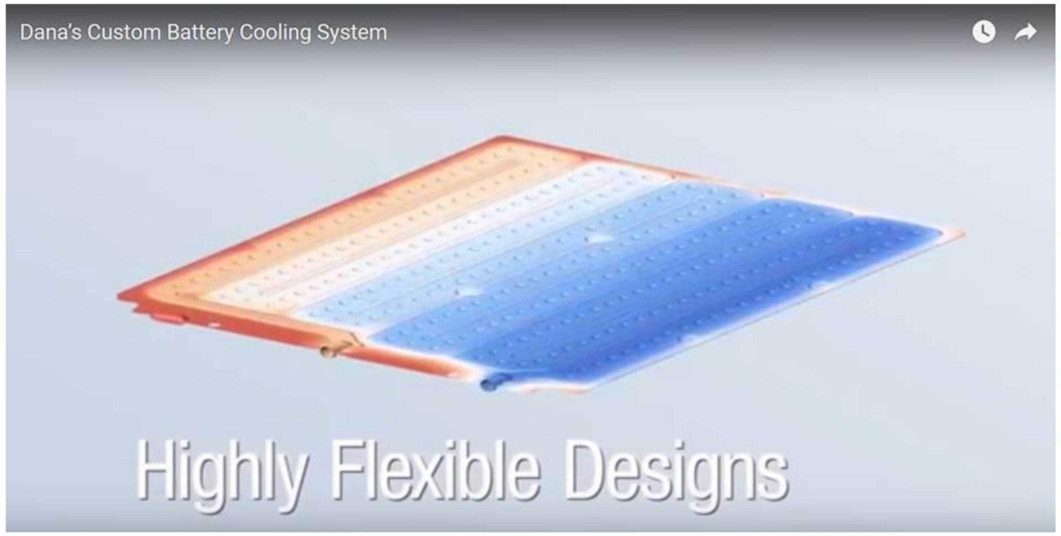
GM's Chevrolet Volt micro channel fins

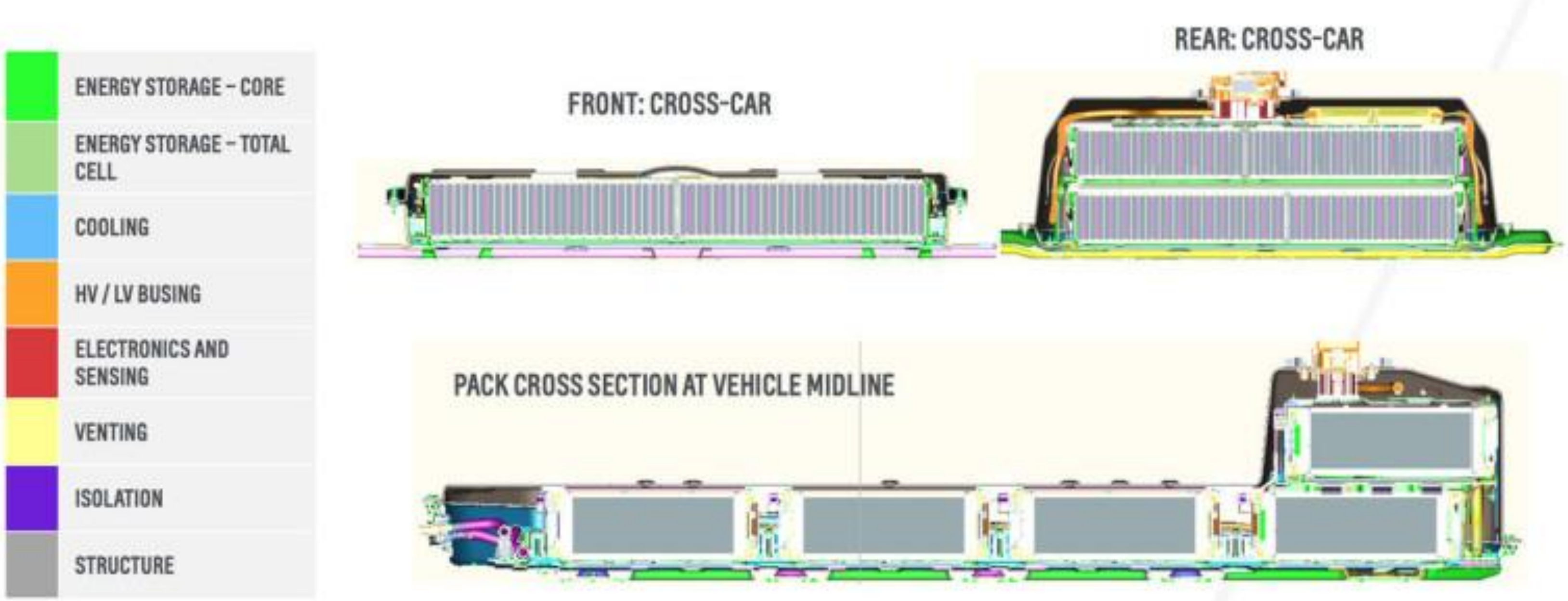


GM's 2017 Chevy Bolt cooling plate

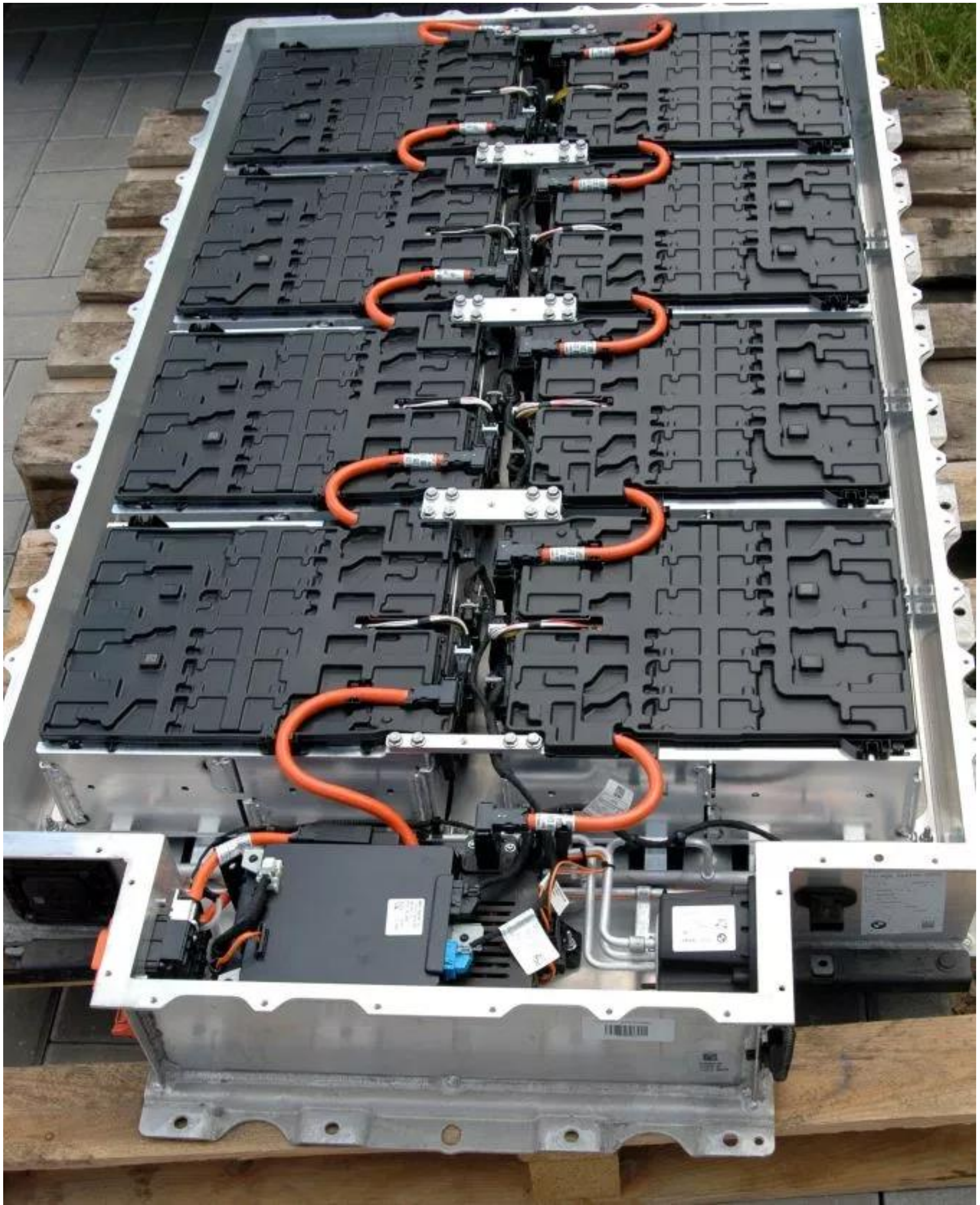


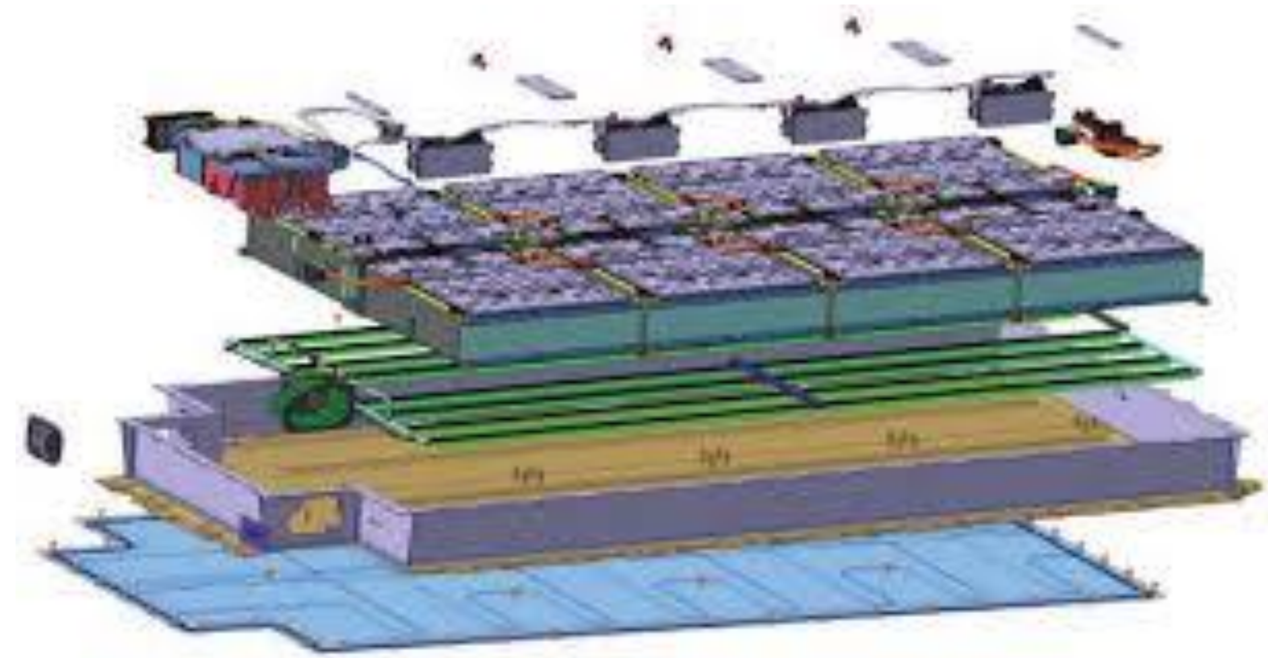




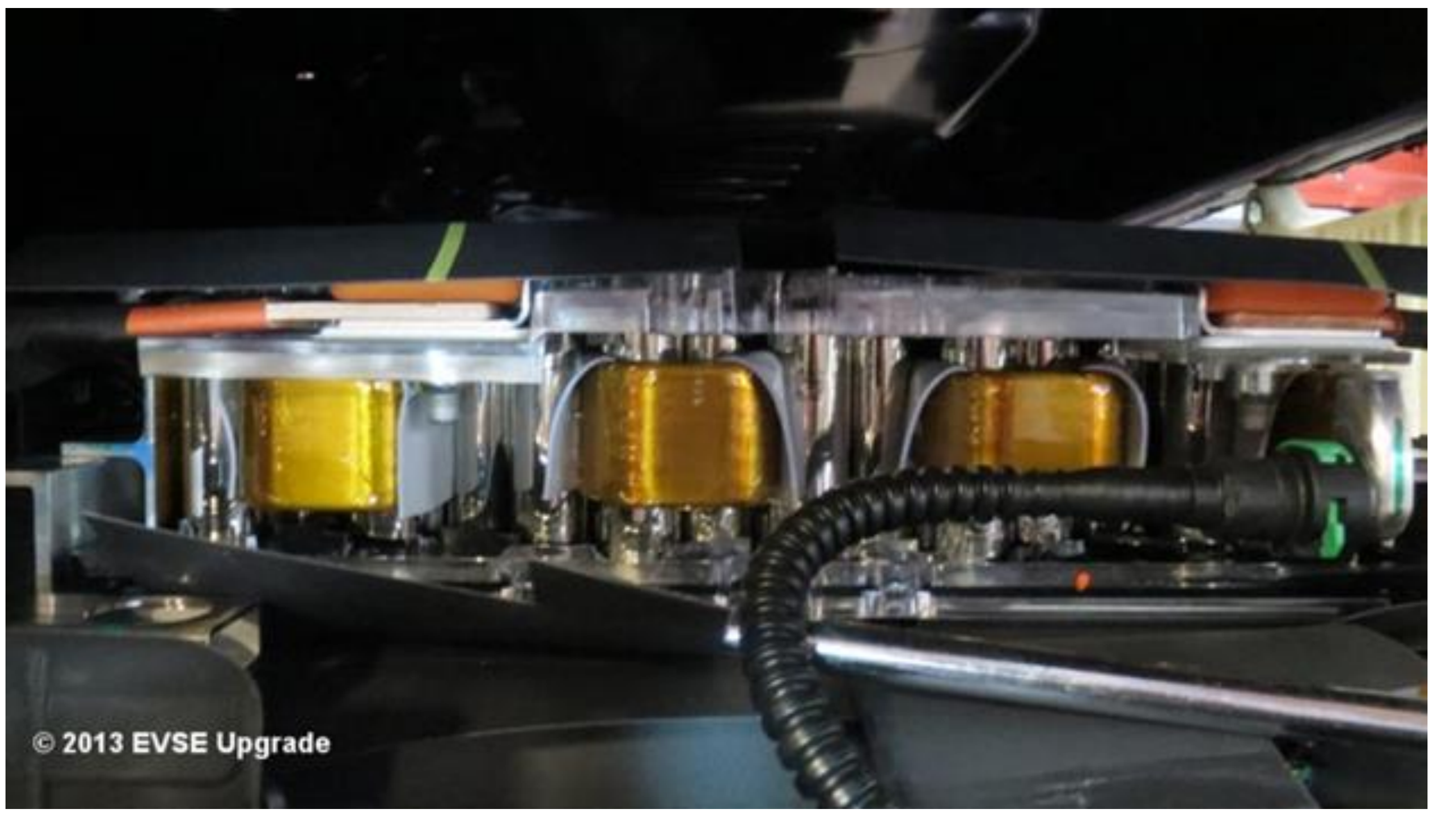


BMW i3 底部冷媒直冷方案



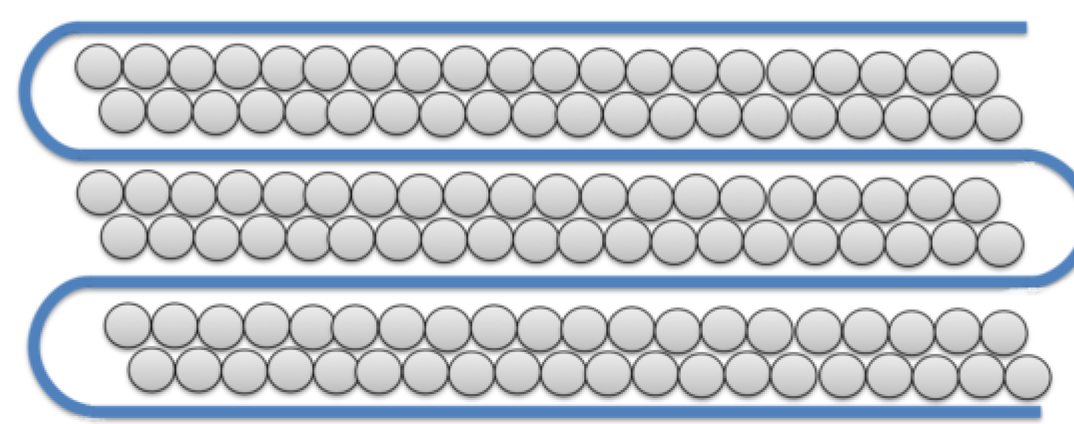


Tesla flexible flat tubes to cool cylindrical cells



Tesla Model S
Coolant in flexible flat tubes
cylindrical cells

Complex
large number of cells
higher failure rate



Tube is lagged with grey heat transfer material and in close contact with side of cells – can be see as "gold ribbon" on tear down pictures of Tesla battery
Single extrusion minimises potential for leaks inside the pack

Performance comparison

	Air-cooling	Liquid-cooling	Remarks
Thermal conductivity (W/(m.K))	0.0242	0.3892	Liquid cooling ~15X more efficient
Cooling/ heating rate	Hours	Minutes	Winter: faster hearing Summer: sustained cooling of batteries, especially on warm pavements
Pack sealing	Air inlet, outlet: can allow entry of moisture, dust	IP67-grade sealing	Allows sealing against dust & moisture
Cell temperature uniformity	Difference >5ºC	Difference <2ºC	Better uniformity, improving performance and service life
Leakage risk	No risk	Minimal	Leakages in liquid cooling can be rapidly detected by sensors No risk of leakage if coolant is dielectric
Effect of ambient temperature	Large	Small	Less risk of overheating with liquid cooling
Integration w/ existing HVAC & drive cooling systems	Limited (can only use HVAC air to cool)	Possible	Possibility of optimizing energy usage
Brake regeneration	Possibility of overheating	Easier to prevent overheating	Current is usually much higher than discharge during brake regeneration - efficient cooling is needed
Fast charging (15-30 min, 2C-4C)	Not sufficient to cool battery	Sufficient to cool battery	Fast charging will cause an increase in heat production - efficient cooling is needed to keep temperatures from exceeding 50-55 ºC for a long cycle life
Cost	Higher costs over shorter lifespan	Lower costs over longer lifespan (EL)	Liquid cooling can double the battery service life

Trend of large battery packs

	Hybrid EV (HEV)				
S/N	**Brand**	**Battery Type**	**Year**	**kWh**	**Cooling**
1	**Toyota Prius**	NiMH	1997	1.31	Air
2	**Ford C-Max**	Lithium-polymer	2003	1.4	Air
3	**Hyundai Sonata**	Lithium-polymer	2013	1.4	Air

	Plug-In Hybrid EV (PHEV)				
S/N	**Brand**	**Battery Type**	**Year**	**kWh**	**Cooling**
1	**GM Chevy Volt**	Lithium-polymer	2011	16	***Liquid***
2	**BMW i8**	Li-ion	2013	7.5	***Liquid***

	Pure Battery EV (BEV)				
S/N	**Brand**	**Battery Type**	**Year**	**kWh**	**Cooling**
1	**Nissan Leaf**	Lithium-polymer	2010	24	Air
2	**iMiEV**	Li-ion	2010	16	Air
3	**BMW Mini E**	Li-ion	2011	35	Air
4	**BMW i3**	Li-ion	2011	22	Refrigerant
5	**Tesla Roadster**	Li-ion (18650)	2008	53	***Liquid***
6	**Tesla Model S**	Li-ion (18650)	2012	45	***Liquid***
7	**Benz B-class**	Li-ion	2012		***Liquid***
8	**Benz SLS AMG Coupe**	Li-ion	2012	60	***Liquid***

Misconceptions

High cost

Complex

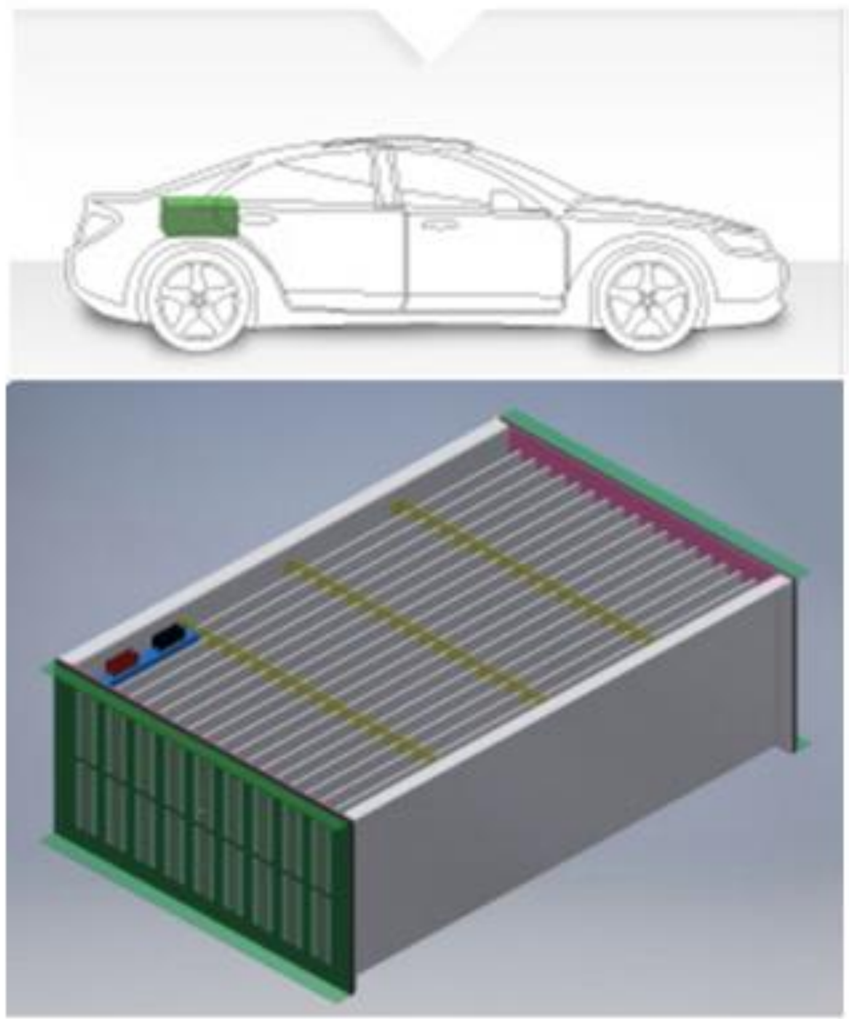
OUR SOLUTION

Video demonstration

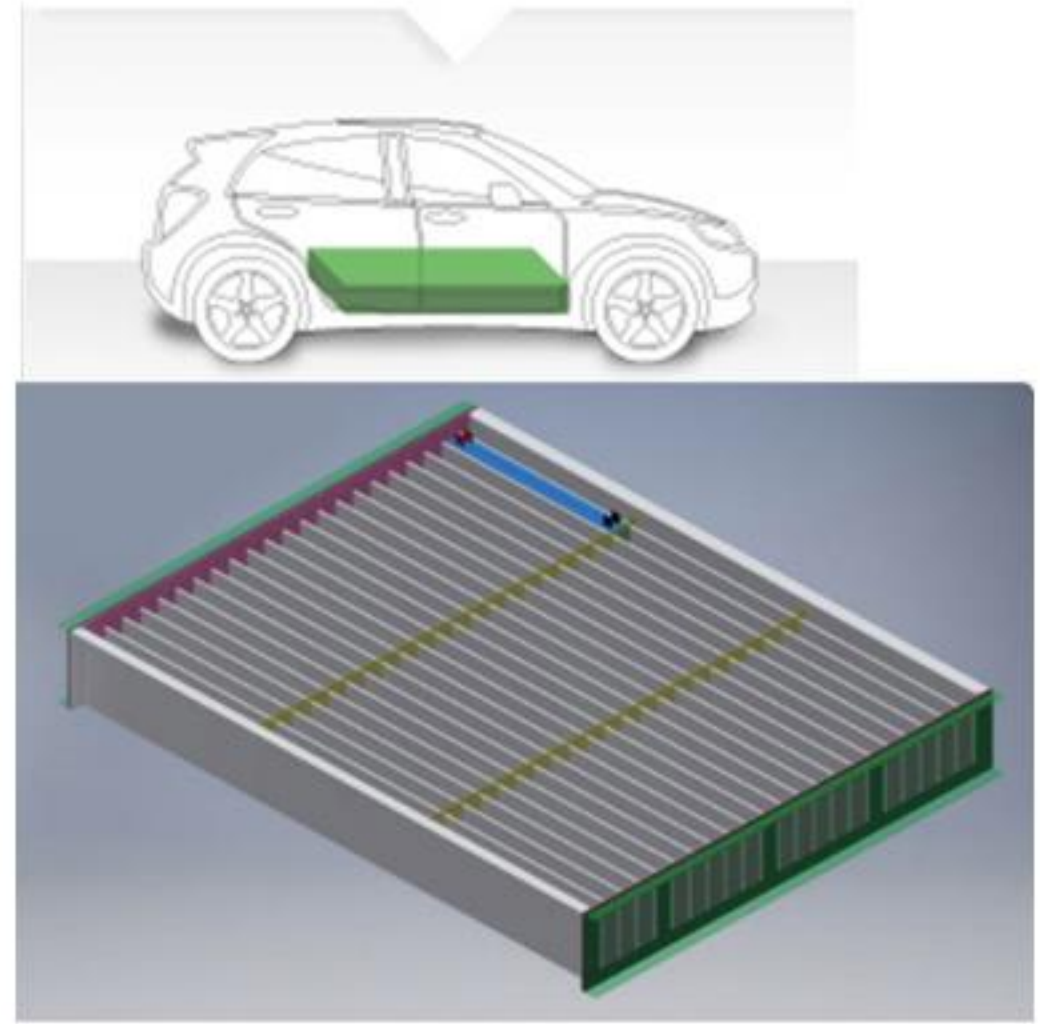
Our solution

Existing problems	Our solution	Benefits
Poor cooling effectiveness and efficiency	Even, effective, and efficient cooling at cell level	Enhance safety Doubled battery longevity
Heavy, large volume	Lightweight, compact	Standard and series possible Plug-and-play capability for quick swaps
Complex, high cost	Simple, low-cost	Eliminate the need for modules Easy maintenance Cost reductions

EV applications



Type A



Type B

		Cell	Pack							
		Cell Ah	Cells (quantity)	kWh	Box length (mm)	Box width (mm)	Box height (mm)	Total weight (kg)*	Wh/kg	Wh/L
Type A	EL-10-A	31.5	90	10.5	623	455	270	88.6	118.4	137.1
	EL-16-A	31.5	136	15.9	808	505	270	**131.4**	**120.6**	**143.9**
	EL-22-A	31.5	190	22.1	993	555	270	180.3	122.8	148.8
Type B	EL-24-B	65	100	23.7	832	1080	160	148.4	159.9	165.0
	EL-30-B	65	126	29.9	1214	920	160	**185.3**	**161.3**	**167.3**
	EL-46-B	65	200	47.5	1596	1080	160	290.5	163.3	172.1

***Total weight includes cells, enclosure, coolant, and battery management system (BMS)**

Prototyping

A battery pack prototype comprising mainly of cells, battery management system, thermal enclosure and pump for circulating the coolant has been showcased.

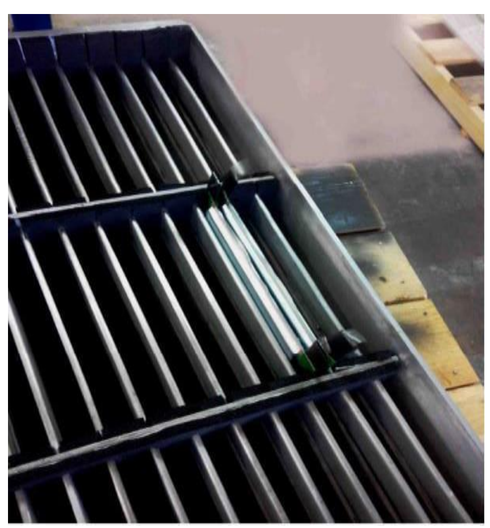
Individual Cells (1)

Cell Couple (2)

Open Enclosure (3)

Coolant Inlet | Outlet (4)

Finished Proof of concept in 2015
Funded by SPRING Singapore
~SGD 250K



Slots for Placing Cells (5)

Thermistor Connections (6)

Battery Pack with Voltage Tap (7)

Battery Pack Assembled (8)

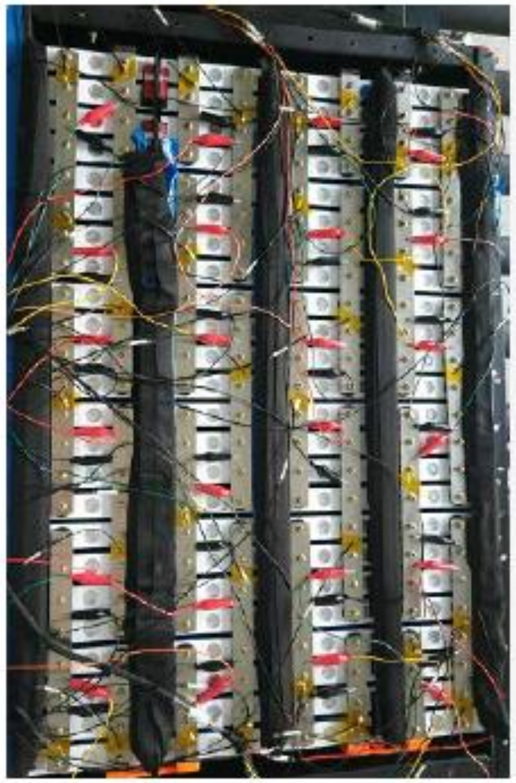
SPRING singapore Enabling Enterprise

NANYANG TECHNOLOGICAL UNIVERSITY

Standard C pack（1060 x 630 x 250 mm),
with 96 pcs of 68 Ah (1. 5 kg/cell) LFP cell,
Capacity: 20.9 kWh, Total weight: 190.15 kg,
Energy density: 110 Wh/kg

实验目的

验证液冷电池包的散热性能。



实验准备

◆ 样品信息：

电芯：磷酸铁锂

额定电压：76.8V

额定容量：224Ah

电芯组合方式：4P24S

◆ 实验环境：

新能源事业部装配产线，实验时温度24~27℃；湿度45~60%，大气压为101~103Kpa。

◆ 设备信息：

瑞能 100V300A 设备　　采购并校验时间2016.10月

实验设计 thermal testing

充放电工步如下：

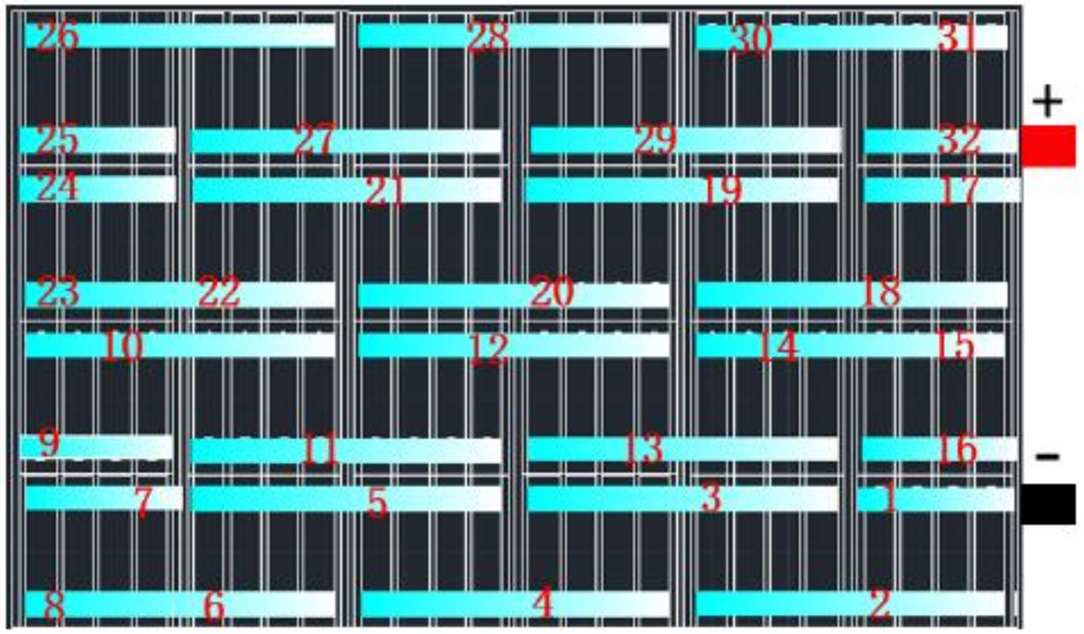
1. 0.5C恒流充电
2. 静置30min
3. 0.5C恒流放电
4. 静置30min
5. 0.5C恒流充电
6. 静置30min
7. 1C恒流放电
8. 静置

测试组别设计：

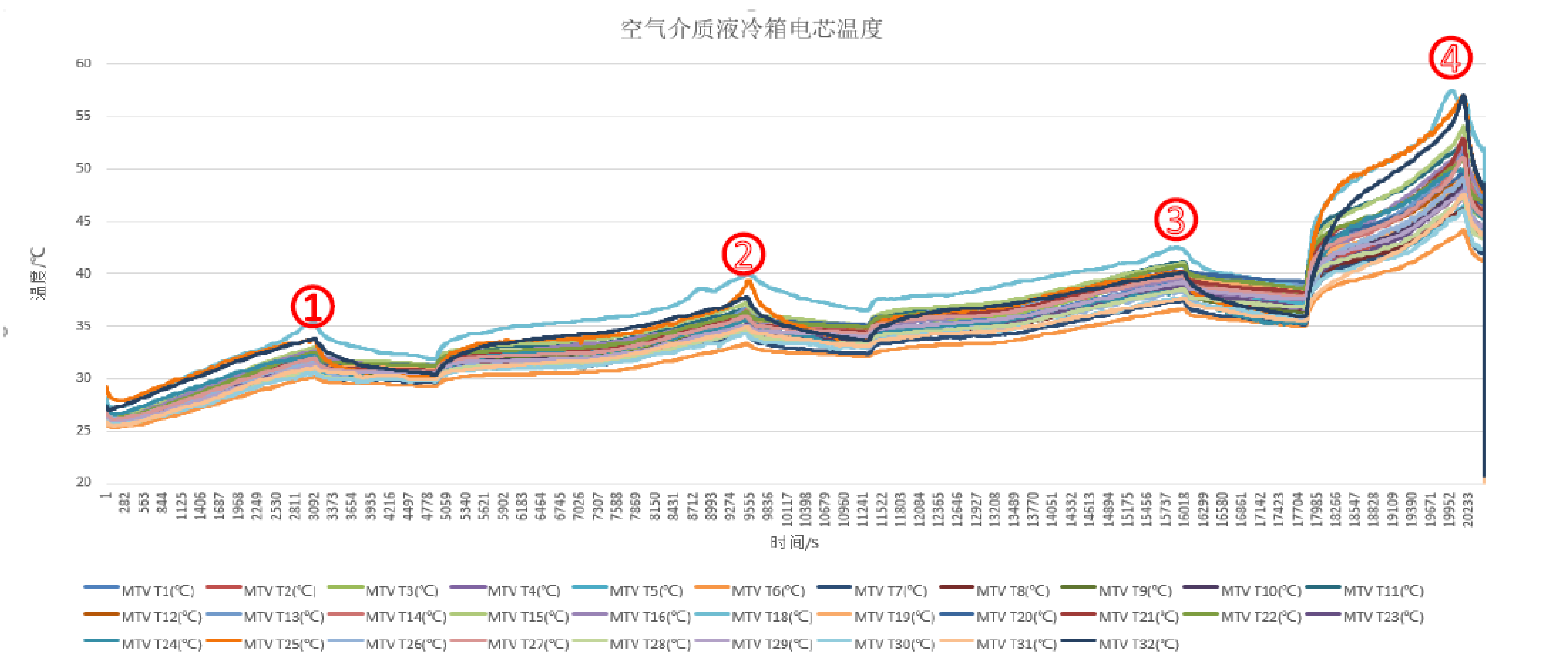
	导热介质	介质流速	记录项
第一阶段	空气	静态	电芯温度
第二阶段	水	静态	电芯温度
第三阶段	水	7L/min	电芯及进出水口温度

注：每阶段结束后静置一夜进行下一阶段测试。

温度采集点分布如下：

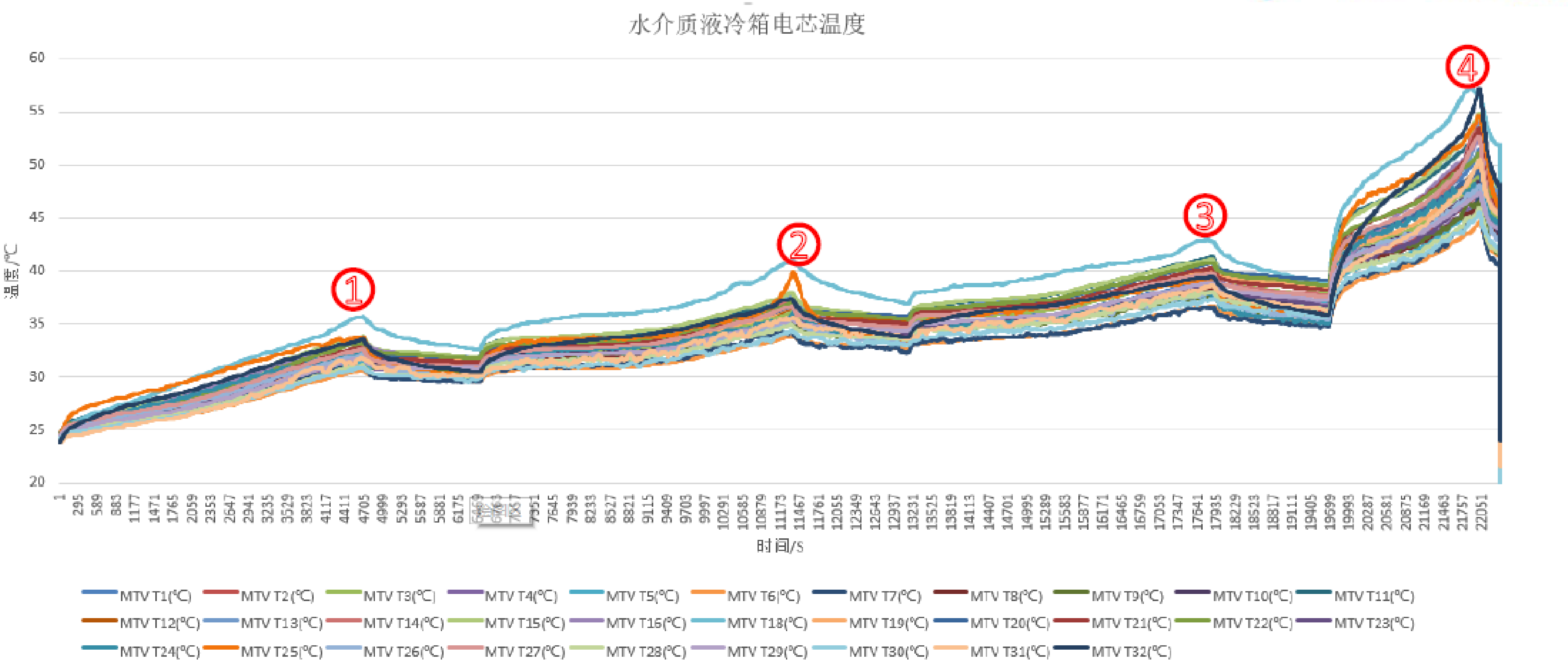


实验结果-空气介质传热 (cool by air)



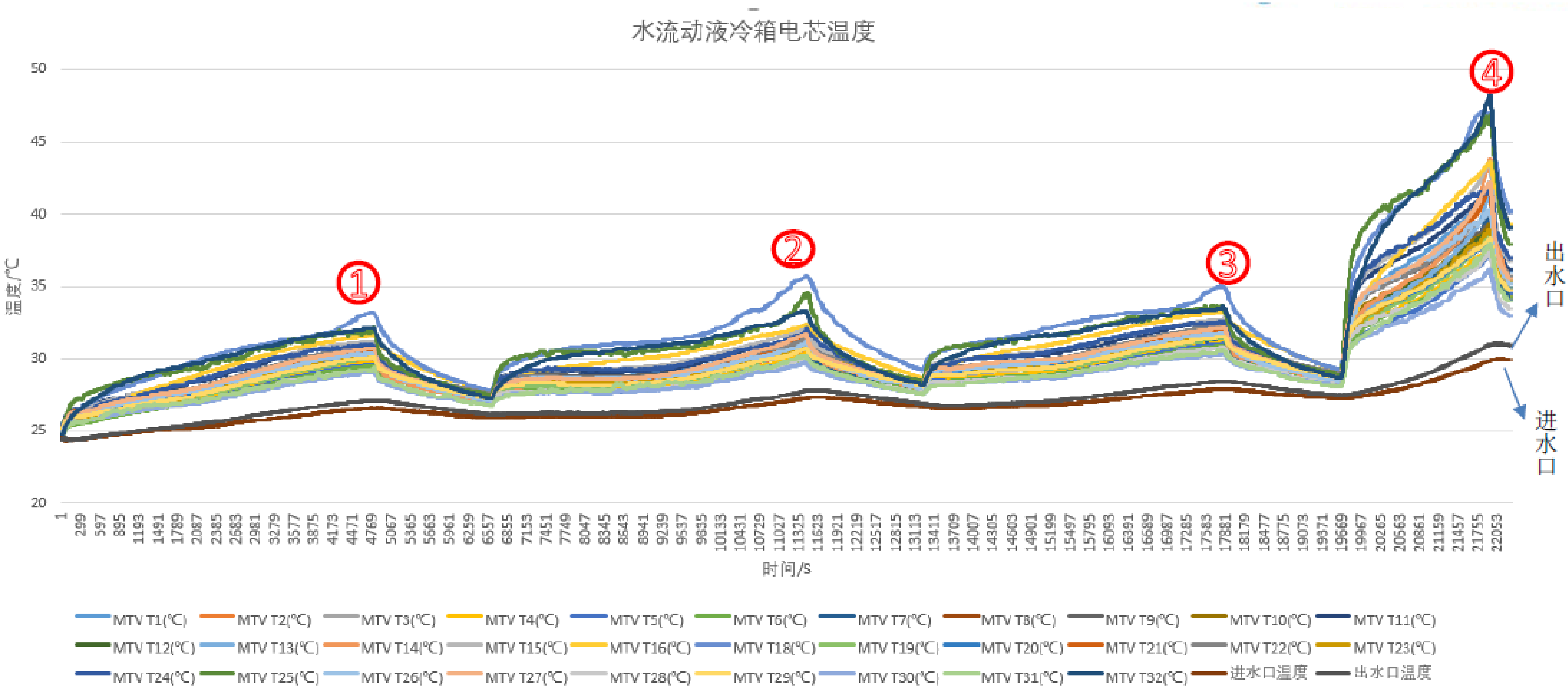
工步	单体最低温度	单体最高温度
1. 0.5C充电结束	30.6℃	35.3℃
2. 0.5C放电结束	34.2℃	39.9℃
3. 0.5C充电结束	37.8℃	42.5℃
4. 1C放电结束	46.0℃	56.5℃

实验结果-静态水介质传热(cool by static water)



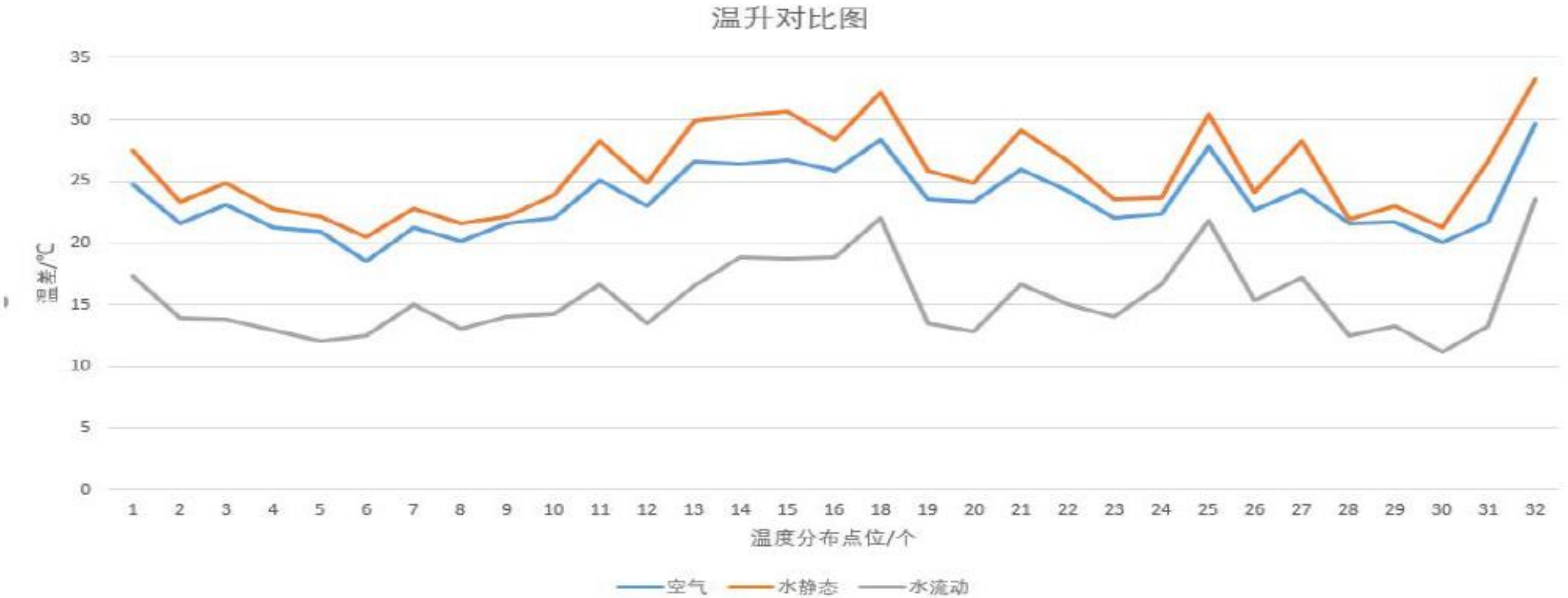
工步	单体最低温度	单体最高温度
1. 0.5C充电结束	30.7℃	35.6℃
2. 0.5C放电结束	33.8℃	41.0℃
3. 0.5C充电结束	36.4℃	42.7℃
4. 1C放电结束	44.6℃	57.2℃

实验结果-流动水介质传热(cool by circulating water)



工步	单体最低温度	单体最高温度	进水口温度	出水口温度
1. 0.5C充电结束	29.0℃	33.1℃	26.61℃	27.13℃
2. 0.5C放电结束	29.7℃	35.7℃	27.36℃	27.83℃
3. 0.5C充电结束	30.4℃	35.0℃	27.90℃	28.42℃
4. 1C放电结束	36.1℃	48.2℃	29.91℃	31.05℃

实验结果-每阶段结束时各温度点温升



散热条件	最小温升 （6号点）	最大温升(32号点)
空气	18.5℃	29.7℃
水静态	24.9℃	33.3℃
水循环流动	11.2℃	23.5℃

Remark：

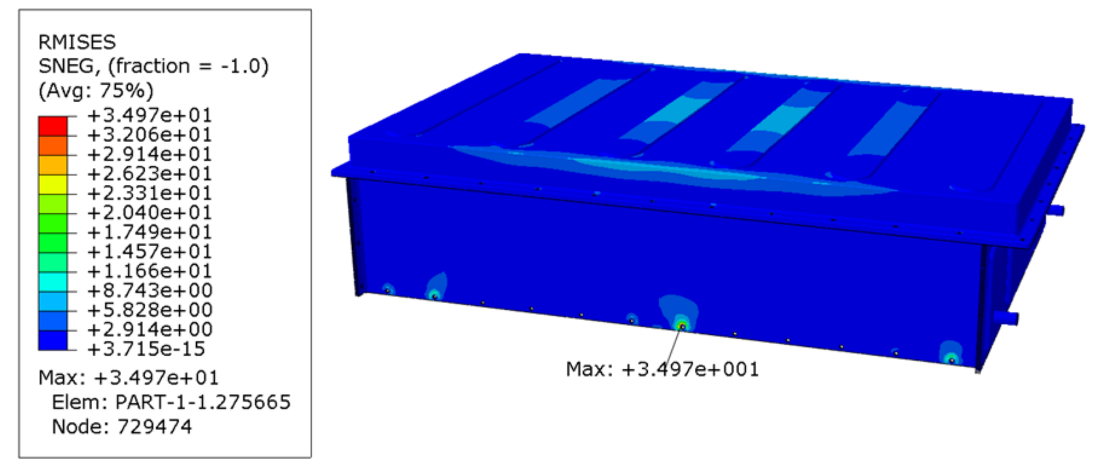
1、此图为各温度采集点充放电结束时温度与初始温度的差值；

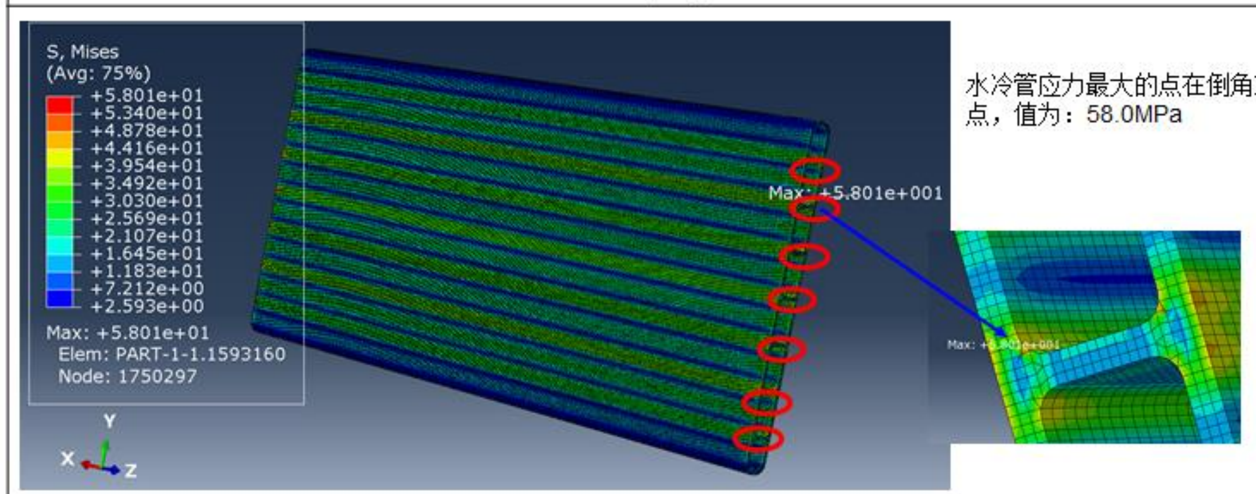
2、因电芯连接方式为铜排螺丝紧固，易形成接触阻抗，故此次测试的温度一致性差、温升高。

Stress analysis of the battery box also meet design requirements

- Random vibration analysis in the direction of battery box Z & Y
- 3G gravity analysis in Z direction
- Pressure analysis of water cooled plate

3.分析结果-铝材料总体Z方向

应力（针对电池模组中的铝制材料）

箱体中铝制材料最大应力为34.97Mpa，小于材料的屈服强度（115MPa/1.5(安全系数)=76.6MPa）

应力
 水冷管应力最大的点在倒角顶点，值为：58.0MPa
水冷管应力最大的点在倒角顶点，值为：58.0MPa，小于材料的屈服强度安全范围（115MPa/1.5(安全系数)=76.6MPa）

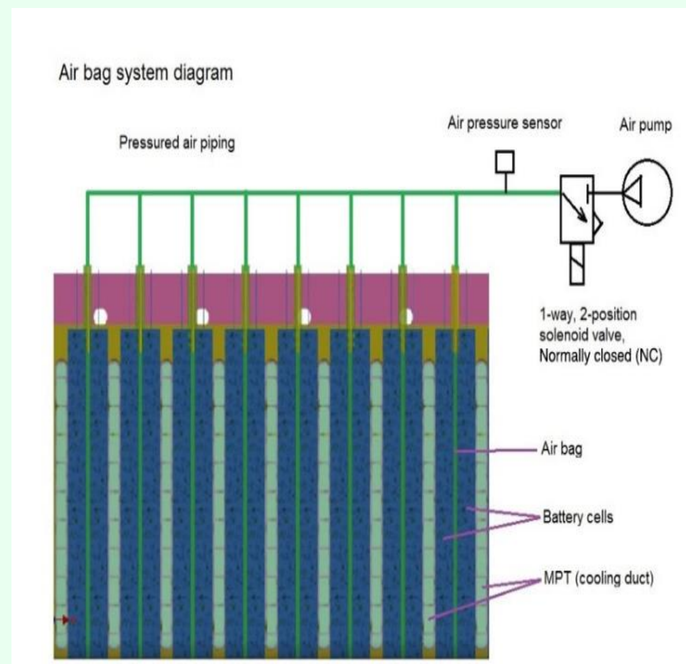
Comparison

	Competitors	EL BP-1
Cell	Smaller cylindrical cells/ laminated cells	Large format laminated cells
Module	Several cells connected side by side Case of the modules keeping the cells in their positions and maintaining its shape	Elimination of the module system, simplifying the whole system and reducing the cost
Pack	Connecting a number of battery modules	Individual cells of the battery pack will be fitted in the spaces between these ducts. The cooling duct plate supports the battery cell and keeps the battery cells in their positions and maintains its shape.
Cooling method	The battery modules sit on or are attached to a **heat sink that is cooled by a coolant loop**. The cooling efficiency is low, and the effectiveness is poor.	This novel structure of the apparatus will be able to **carry coolant to each individual cell evenly**, effectively and efficiently.
Complexity	Complex	Simple
Swappability	No	Yes
Cost	High	Low

Competitive Performance

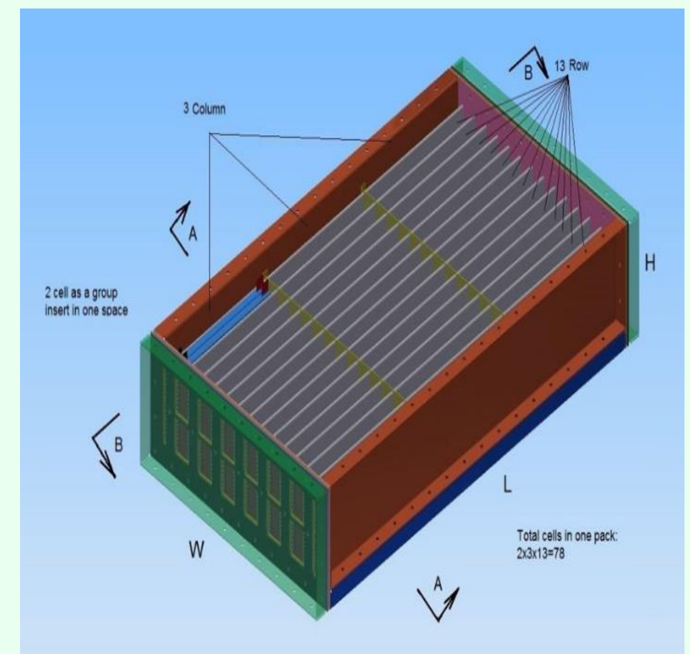
Existing Solutions

Due to bulk size and shape of module, it is not flexible to arrange modules in a constrained space in most application.



EL –Uniform Cooling & Pressure

Pressure from foam or the air bag ensures uniform contact of the battery cells with the MPT cooling surface



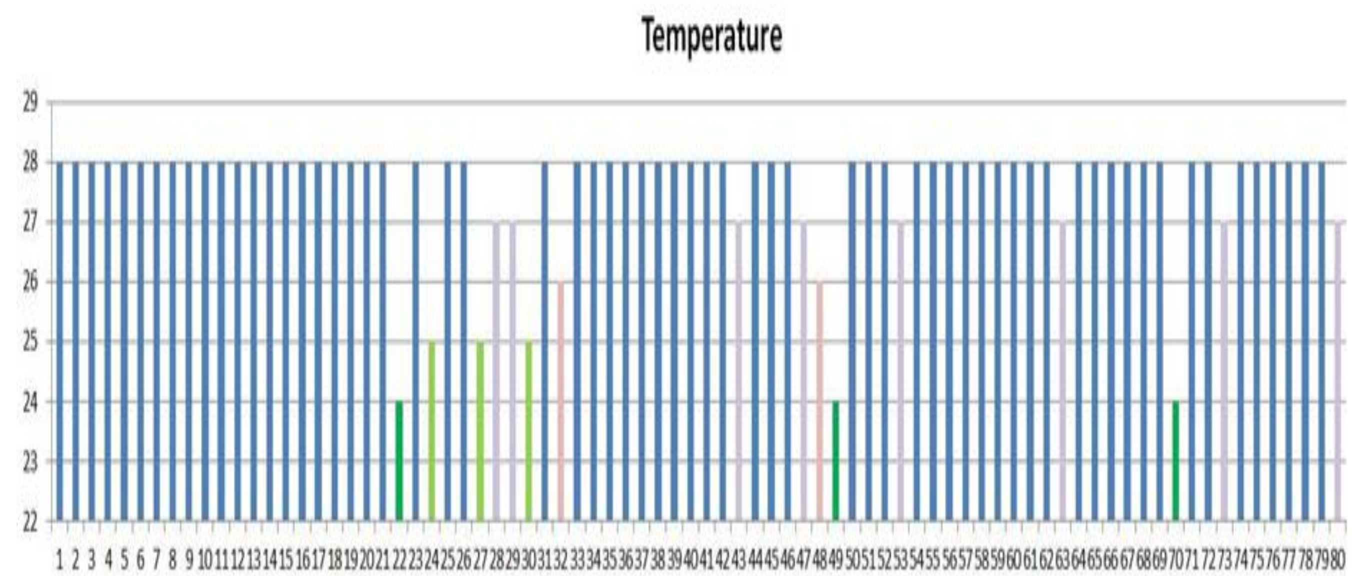
EL- Higher kWh/L & kWh/kg.

Due to small size and shape of cell, it is flexible to arrange more cells in a constrained space

Comparison of specifications

	Nissan Leaf	BYD	Tesla	Saft	Volt	Dow Kokam	EL
Cell type	Pouch	Prismatic	Cylinder	Cylinder	Pouch	Pouch	**65Ah Pouch**
Coolant	Natural air	Air	Liquid	Liquid	Liquid	Liquid	**Liquid**
Pack kWh	24	48	60	9.2	16	7.1	**29.9**
Total weight (kg)	294	700	450-510	140	197	90	**185**
Wh/ kg	82	69	117-133	66	81	79	**161**
Size (LxWxH, mm)	1570 x 1188 x 265*	1750 x 950 x 300	2700 x 1500 x 100	890 x 470 x 229	1670 x 250 x 250	730 x 280 x 280	**1214 x 920 x 160**
Volume (L)	250	499	430	96	151	57	**179**
Wh/ L	96	96	120 ~ 140	96	106	124	**167**

Cost Competitiveness



Designed for mass manufacturing
Continuous atmospheric brazing enclosure – strong, lightweight, consistent quality with low costs.

Increased battery safety and battery service life
cells temperature maintained 15 ~ 35° C;
temperature evenness < 4° C

IP Position

China

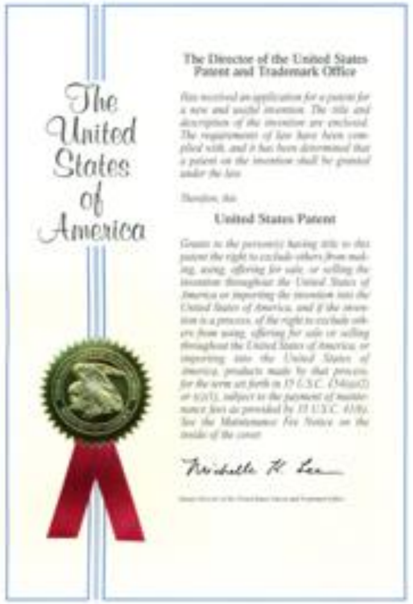
Singapore

EU

Japan

Korea

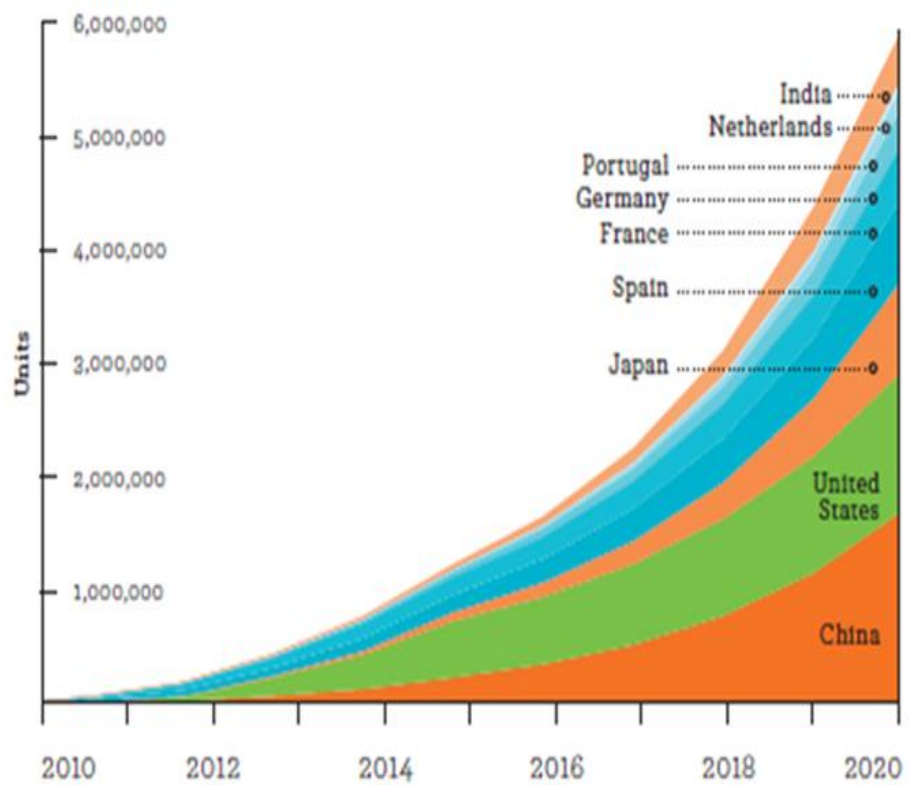
Taiwan



US

EVs Market Potential

Figure 2. EV Sales Targets [select EVI members]
Source: EVI. Note: A 20% compound annual growth rate is assumed for countries without a specific sales target (i.e., only a stock target) or with targets that end before 2020.



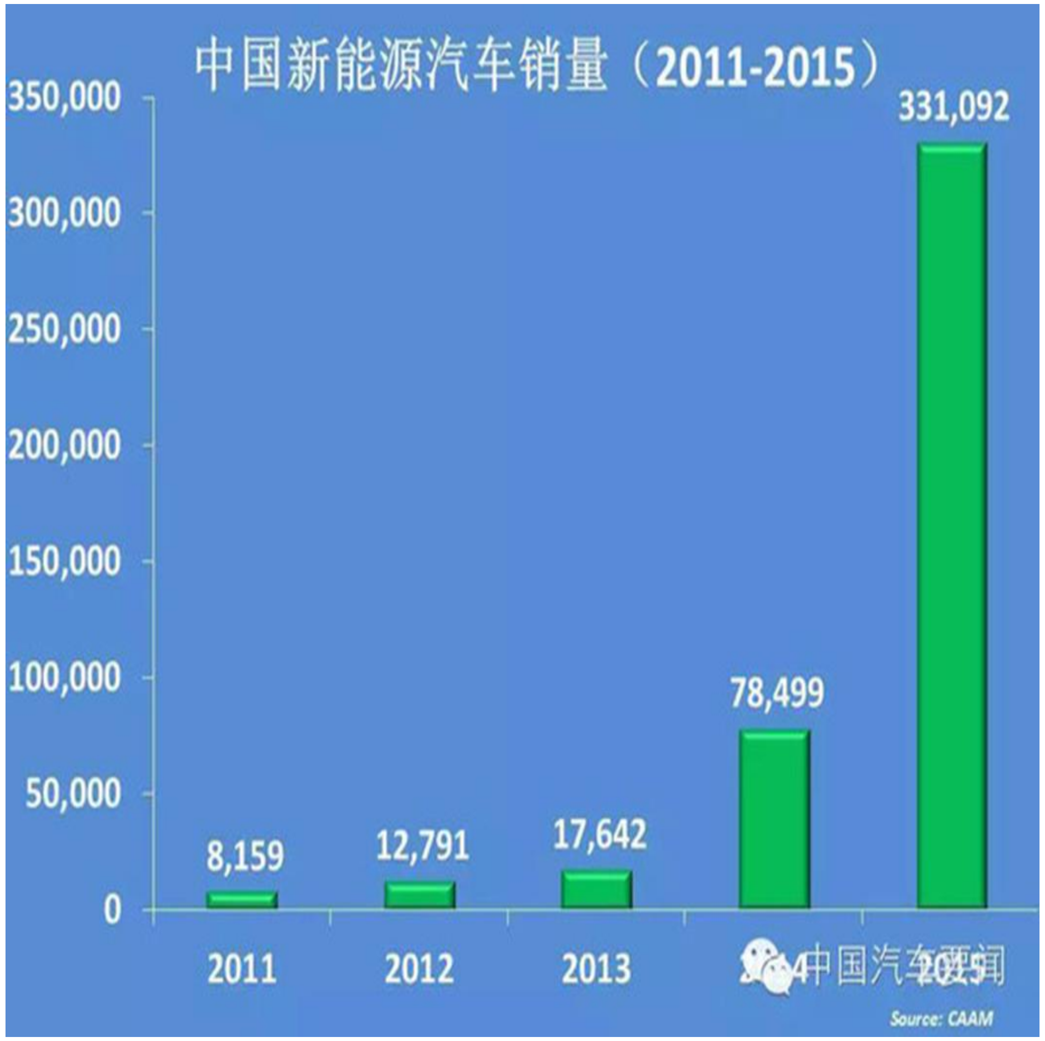
The world market volume by 2020:

Evs world annual sales: **5 ~ 6 million**

Battery pack market volume:
U$44 billion

Battery pack thermal control system & enclosure market volume:
U$4.8 billion

China EV & LEV Market



By 2020 5% of new car sales in China will be that of electric cars: **1 million** EVs annually

LEVs upgrading from lead acid batteries to Li-ion batteries represent a huge market potential for our company

Energeia Labs – Market Positioning

- A novel integrated liquid cooling battery pack enclosure

- A simplified module-less battery pack assembly

Products Roadmap

- A typical validation product
- Series standard product
- Product for other application
- Promote to the world

	2018	2019	2020	2021
EL Products	Customizing the BMS design			
	Optimizing battery packs for HEV, PHEV and EV in next 18 months.			
		Roll out EL Products Range ~22-32kWh		
			Exploring application for LEV, E-motorcycle, marine, solar and wind ESS, IT UPS in 3 years span.	
EL Services			**Developing smart battery pack systems** *(like tracking of battery pack location, indication of battery pack swap station nearby, real-time monitoring and communicate with mobile phones or control centre)*	

Business Models

Flexible and adaptive, including:

- Direct sales of enclosure and battery pack
- IP licensing
- After sale service.

Sales target

2019 EL targets sales of 10,000 sets

(~1.6% of 0.6million EVs market share in China by 2019)

Execution Roadmap

Funds Sought

SGD 1 Million

(￥5百万元）

	2018	2019		
	Jul-Dec	Jan-Mar	Apr-Jun	Jul-Sep
FinaL Product Design/ Development Assembly and QC	SGD 300,000: Target Market Ready Product			
Customer trials and design validation	SGD 200,000: 3 customers validation			
Legal, compliance & certification		SGD 300,000: Ccertification complete		
Beta launch, market entry into Asian region			SGD 200,000: Marketing & Showcase	

Road To Market
In the next 18 months

Cost
Manpower ($400,000)
Testing - Target 3 core customers Pilot – Trials ($200,000)
R & D， Hardware- Fabrication/ Procurement ($200,000)
Market Launch – Showcase ($200,000)

Team members

- **Feng Guoan** In 1986 graduated from the Department of mechanics of University of Science and Technology Beijing. Senior design engineer, 9 years of design experience in China institute and 23 years design experience abroad. The founder of the Energeia Labs Singapore, is responsible for the overall charge.

- **Xiao Lifeng** In 1995 graduated from the mechanical electronics department of Xi'an University of Electronic Science and Technology. Battery Pack senior engineer, 23 years working experience where Dongfeng 4 years, NOKIA 5 years, BYD 10 years.

- **Chao Ya Jun** In 1997 graduated from Zhejiang University with Ph. D. in electrochemistry. Battery material expert, 20 years working experience where CATL 5 years, BYD 10 years.

- **Chen Yang** In 2013 graduated from the Jilin University, master of thermal management. The main research direction is the battery thermal management . Worked in the SAIC passenger car intelligent vehicle department (ADAS). Involved in the major research projects of battery thermal management in Shandong Tian Bo.

Teams and partners

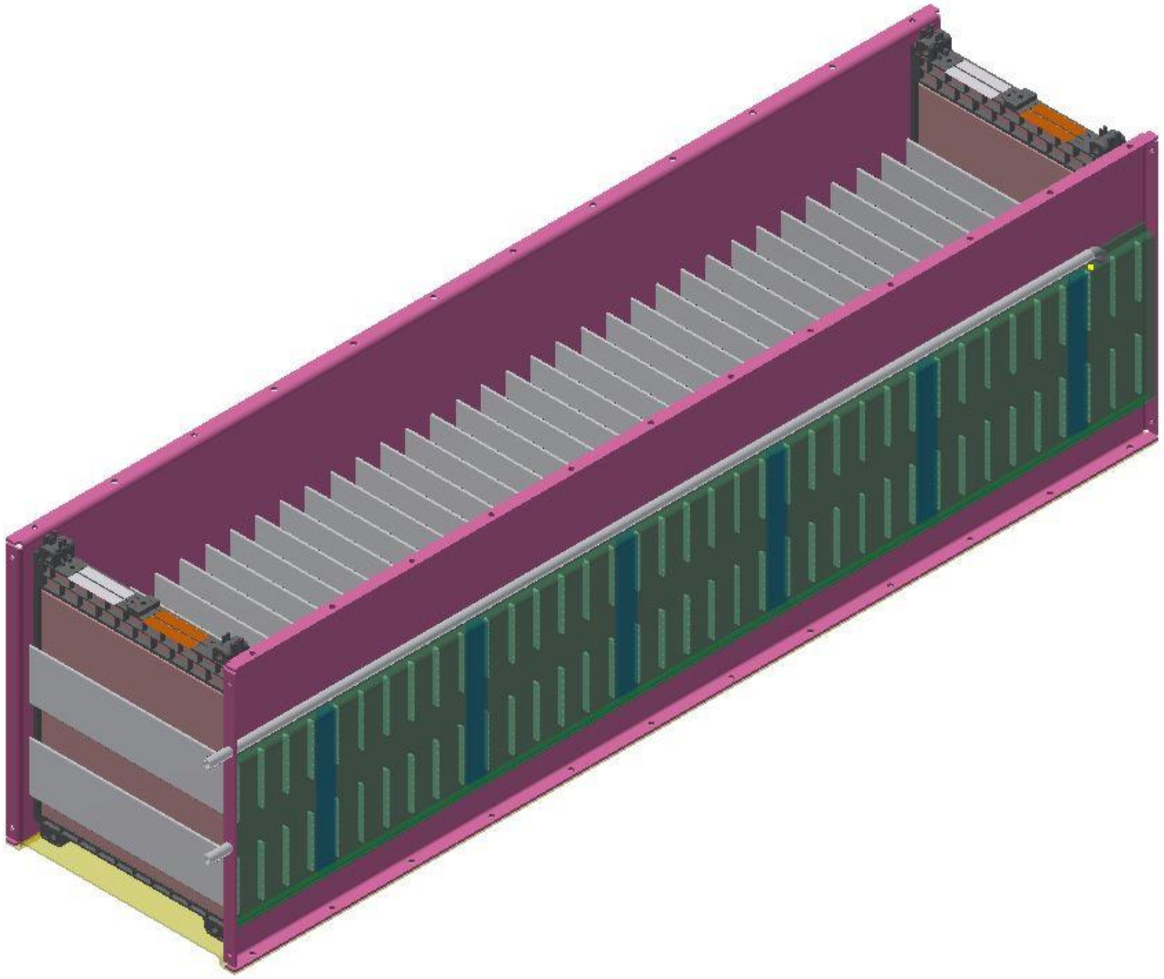
- Energeia has a close production and manufacturing partner in China and Europe, which can satisfy the mass production of products and the price is competitive.

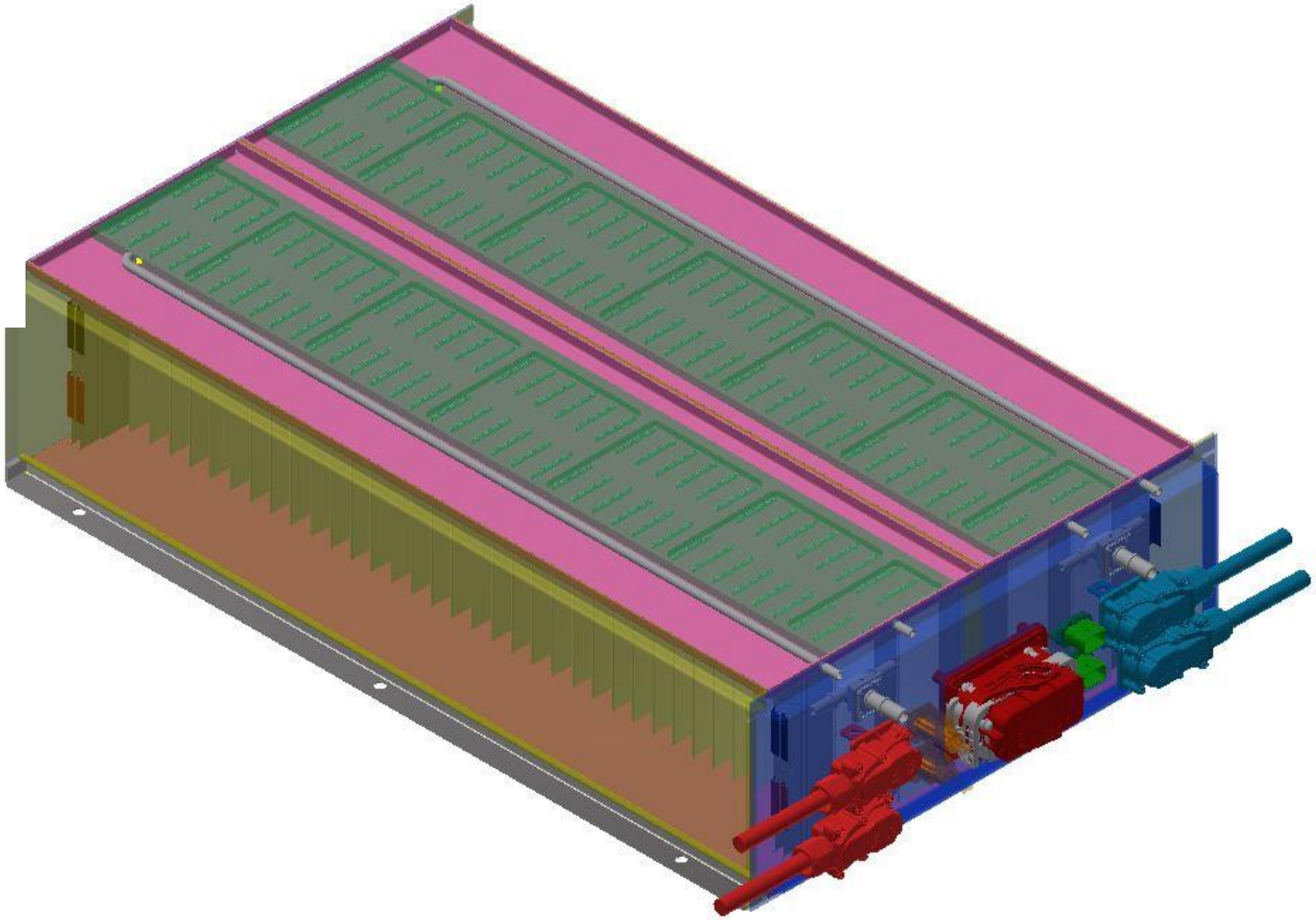
- Currently, partners and agencies in Singapore, China and South Korea are helping to carry out market promotion.

- After get external finances, the full-time sales staff and R & D personnel will be recruited.

- The company's strategy is to master core technology, integrate good quality resources, provide high performance low cost products, run business with light assets to lower risk and develop steadily.

Cooperation - a win-win case





Energeia Labs
恩能吉尔实验室

1 We developed a patented liquid –cooling & heating battery pack systems

2 Key Product: Battery Packs for HEV, PHEV, EV and ESS

3 Market Size: 5 Million Sales by 2020 Target Segment: EV-OEM's， ESS

4 Fund Sought : SGD 1.0 Million;

5 Our technology make battery pack: Safer, performance well, fast charging possible and low it's cost.

Feng Guo An冯国安

+65 - 9239 2809
+86-13681833895
fengga@el.sg
http://el.sg