新能源汽车的技术发展趋势

New energy vehicle technology trends

预致汽车咨询有限公司和
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The China NEV technology roadmap: Emerging trends

The emergence and sustainability of new energy vehicles (NEVs) require adjustments in old vehicle platforms, which will take time for customers to accept. Additionally, the development of auto technology will drive NEVs to become a major trend. Original equipment manufacturers (OEMs) need to figure out how to balance NEV manufacturing costs with technological innovation in order to lead a new round of automotive technology development and market share expansion. NEVs mainly refer to pure battery electric vehicles (BEV), plug-in electric vehicles (PHEV) and fuel cell vehicles (FCEVs).

Battery technology, motors and cost development

Most EVs use nickel-metal hydride (Ni-MH) batteries and lithium-ion batteries as power sources. Ni-MH batteries are durable, affordable, create less pollution, and can be mass produced. In addition, they are relatively cheaper to manufacture, while the technology behind it is more mature. As a result, large Japanese OEMs tend to use them for their hybrid models.

However, Ni-MH batteries have lower energy density than lithium-ion batteries, and are therefore not suitable for pure BEVs. Lithium-ion batteries, on the other hand, are high voltage and have high energy density. Under the same weight conditions, the capacity of lithium-ion batteries is 1.6 times higher although only part of their full potential are used. Lithium-ion batteries are more common in NEVs.

The cathode materials used in lithium-ion batteries for most international NEV models are lithium manganese oxide (LMO) and ternary (NCM/NCA), while Chinese NEVs mostly adopt lithium iron phosphate (LFP) batteries. As at the end of September 2017, China has launched 4,981 EVs, with 3,147 (or 63 percent) using LFP batteries, followed by ternary (19.7 percent) and LMO (11.1 percent).[1] To improve battery energy density, many Chinese car

1. 'Catalog of Vehicle Purchase Tax Exemptions on New Energy Vehicles (1-12 Batch)', Ministry of Industry & Information Technology (MIIT), 2017

manufacturers have adopted ternary lithium batteries for their EV models, including BAIC E Class, JAC Heyue and Chery eQ. Ternary is the mainstream cathode material for NEV batteries.

Major global power battery suppliers include Panasonic, AESC, LG Chemical and Samsung SDI. However, China has also emerged as a key battery supplier over the last decade. Companies such as BYD, Hefei Guoxuan, Ningde Era, TianKin Lishen Battery, Pride, China Aviation Lithium Battery Co., Ltd. and Wanxiang Group, are emerging and have achieved significant market share. BYD, for example, is the largest LFP battery supplier in terms of capacity. According to its 2015-2020 technical plan, BYD is focusing on LiMnPO4, which has a battery energy density of around 150wh/kg. Other suppliers are switching from LFP to ternary-based batteries. According to the MIT's action plan to promote the automotive power battery industry, China's lithium battery energy density[2] will reach 300-350wh/kg by 2020, while the battery industry has made a conservative estimate of up to 250wh/kg. Barring any major technological breakthroughs, the improvement of lithium battery performance will mainly depend on material optimisation. Under this assumption, China's lithium battery power energy density is predicted to reach 320wh/kg by 2025.

Meanwhile, there has been a rapid decline in the cost of lithium batteries, decreasing from more than RMB 3,000/kWh in 2011 to RMB 1,700/kWh in 2017. Market participants predict the price of lithium batteries is likely to fall below RMB 1,000/kWh by 2020. The ratio of cathode material, anode material, separator and electrolyte organic solvent to the battery cost is 30:10:25:15.[3] Cathode is the main price determinant as the costs of the other parts are hard to reduce.

Permanent magnet synchronous motors (PMSM, including BLDCM), alternating current (AC) asynchronous motors and AC induction motors (ACIM) are the mainstream motor types, with PMSM the most widely used. The rated power of local EV models is mostly between 20kw and 35kw. BYD's Qin, a PHEV, has a rated power of 40kw, the highest among local models. Sports models, such as Tesla Model S, can reach 100kw. The power density of top EV models globally is between 3kw/kg and 6kw/kg.[4]

2.Source: 'Promoting Automotive Power Battery Industry Development Action Plan', Ministry of Industry & Information Technology (MIIT), February 2017
3&4. Source: 'China New Energy Vehicle Market Semi-annual Report', AutoForesight research, September 2017

NEV platform development strategies

The development of an EV platform hinges on technology and costs. There tends to be three options: develop a new EV platform; cooperate to jointly develop new platforms; or transform an existing internal combustion engine vehicle (ICEV) platform.

Transforming an existing ICEV platform can lead to better cost control. However, there are limitations as the heavy battery pack requires a specific type of design. Since an ICEV platform was not designed to accommodate for a battery pack, there is limited space for its inclusion. This results in lower battery capacity and therefore, shorter mileages.

The battery pack in new EV platforms can be installed on the vehicle floor to increase battery capacity. This allows its weight to be evenly distributed across the axle, while the vehicle would also enjoy a lower centre of gravity and more internal compartment space. However, the development of new platforms requires large financial investments. If sales are limited initially, it will take time for companies to break even, which could hamper their financial performances. This is why models produced using a new EV platform are generally more expensive.

Some manufacturers would team up to jointly develop and share new EV platforms in order to reduce costs. However, many OEMs such as Tesla, Volkswagen, General Motors and Mercedes-Benz still develop new platforms of their own.

BEVs & PHEVs: The importance of technology

Domestic policies tend to promote BEVs over PHEVs. The OEM Average Fuel Consumption & NEV Credit Points Administration Method (Draft for Comments) stipulates that BEVs will get two to six points based on their driving range. All PHEVs, on the other hand, only get two points.[5]

This policy differential is down to a number of reasons:

China's BEVs, for example, have an average mileage of 150km-200km, while PHEVs can reach further distances.[6] However, the energy density of BEV lithium batteries is rapidly increasing. Combined with the fact that its manufacturing costs is also decreasing, the average mileage of BEVs is expected to reach about 400km within the next five years – comparable to PHEVs.

On the other hand, PHEV's inherent structure, which integrates two sets of power systems from BEVs and ICEVs, meant they are expensive and relatively heavy. All three forms of plug-in hybrids - parallel hybrids, series-parallel hybrids and series hybrids - have their own set of weaknesses:

- When parallel hybrid vehicles are in hybrid mode, their fuel consumption is high, while the motor cannot simultaneously generate electricity and propel the wheel.
- Series-parallel hybrid cars have two motors, leading to added weight and a relatively complex control system.
- In series hybrids, the engine and generator do not directly propel the wheel. This leads to power wastage. In addition, there is no significant reduction in weight, while fuel consumption is high at high speeds.

Once BEVs and ICEVs have similar mileages, PHEVs are likely to lose their attractiveness due to its costs, weight and more complex control system. They are, for the time being, a transitional solution to BEVs.

This is a stark contrast to three years ago when most OEMs do not have an NEV technology roadmap and were focusing on PHEVs. The situation has changed with BEVs now the main focus of manufacturers. For example, Volkswagen announced that by 2025, their NEV production will mostly be BEVs. Toyota has also recently moved to re-establish its de-commissioned EV department.

5.OEM Average Fuel Consumption & NEV Credit Points Administration Method (Draft for Comments), MIIT, September 2017
6.'Catalog of Vehicle Purchase Tax Exemptions on New Energy Vehicles (1-12 Batch)', MIIT, 2017

EVs for autonomous driving

BEVs are more suitable for autonomous driving than internal combustion engine models. Firstly, self-driving cars need to configure a large number of sensors, and advanced computing hardware and software, which results in higher power consumption. Compared with ICEVs with 12V battery-supported electrical systems, BEVs are equipped with high voltage and high energy batteries, which enables more freedom in the design of autonomous driving hardware and software.

Secondly, the majority of BEVs and PHEVs are equipped with a wire-controlled electronic control system that is structurally compatible with automated driving. A wire-controlled electronic control system offers better response speed to acceleration/deceleration and braking. There are also fewer mechanical parts compared to an internal combustion engine, which contains about 2,000 components, resulting in a lighter vehicle. Many companies that are developing automatic driving technologies, such as General Motors, Nissan and Google, have picked electric cars as the starting platform for their autonomous driving prototypes.

Fuel cells as an alternative

Fuel cell EVs (FCEVs) are less common in China. Japan and other Western nations are ahead in the development of this segment, which can be reflected by the lack of progress in subsidy policies for hydrogen vehicles.

However, the government is starting to focus more on FCEVs. The Ministry of Industry and Information Technology's (MIIT) strategy paper on the automotive industry outlines plans to promote FCEVs and have them ready for mass production. It aims to achieve 100,000 units on the road by 2030.[7] Shanghai is targeting 5-10 hydrogen stations and 3,000 FCEVs by 2020.[8]

It remains to be seen whether fuel cells can be a success due to the high costs involved. In addition, it requires the construction of a sufficient number of hydrogen refuelling stations. The industry generally believes it will take another 15-20 years for FCEVs to fully take off. In spite of the increasing emphasis on FCEVs, the future landscape of the China automotive industry is likely to see FCEVs coexist with BEVs. This is due to a difference in market positioning as a result of the former's long-distance driving capabilities.

7. 'Middle to long-term Automotive Industry Development Plan, MIIT, April 2017
8.Source: 'Shanghai Fuel Cell Vehicle Development Plan', Shanghai Science & Technology Committee, September 2017

中国新能源车技术路线图 – 未来趋势

新能源汽车的兴起和可持续发展要求对过去的汽车平台进行调整，客户需要时间来接受和适应。此外，汽车技术的发展将使新能源汽车成为主要趋势。整车制造商需要弄清楚如何平衡新能源汽车的制造成本和技术创新，以引领新一轮汽车技术的发展和市场份额扩张。新能源汽车主要指纯电动汽车、插电式混合动力汽车和燃料电池汽车。

电池技术、电动引擎及开发成本

大多数新能源汽车都使用镍氢电池和锂离子电池作为动力源。镍氢电池耐用，价格适中，污染少，能够大规模生产。此外，镍氢电池生产成本较低，技术更加成熟。因此，日本各大整车制造商倾向于在混合动力汽车车型中使用镍氢电池。

然而，镍氢电池比锂离子电池具有更低的能量密度，并且不适用于纯电动汽车。另一方面，锂离子电池具有高电压和高能量密度。在重量相同的情况下，锂离子电池的容量是镍氢电池容量的 1.6 倍。尽管目前只能利用其部分的潜力，但是锂离子电池在新能源汽车中使用更广。

大多数国际新能源车型使用的锂离子电池正极材料是锂锰氧化物和三元（NCM / NCA）材料，而中国新能源车大多使用磷酸铁锂电池。截止至 2017 年 9 月，中国已经推出 4,981 辆电动汽车，其中 3,147 辆（占 63%）使用磷酸铁锂电池，其次是三元材料（19.7%）和氧化锂锰（11.1%）[1]。为了提高电池能量密度，许多中国汽车制造商（包括北汽 E 系、江淮和悦和奇瑞 eQ）在电动汽车车型中已经使用三元锂电池。三元现在已成为新能源车用电池的主流正极材料。

1. 工业和信息化部《免征车辆购置税的新能源汽车车型目录》（第 1-12 批），2017 年

全球主要动力电池供应商包括松下、AESC、LG Chemical 和三星 SDI。而过去十年间，中国已经成为重要的电池供应商，比亚迪、合肥国轩、宁德时代、天津力神、普莱德、中航锂电、万向集团等国内动力电池供应商正在崛起，并取得显着的市场份额。例如，按容量计算，比亚迪目前是最大的磷酸铁锂电池供应商。按照其 2015 - 2020 年技术规划，比亚迪将把重点放在电池能量密度接近 150wh / kg 的锂离子电池正极材料上；其他供应商正在从磷酸铁锂转向基于三元的电池。根据国家工业信息部发展汽车电池工业的计划，国家规划的锂电池能量密度将达到 300-350wh / kg，而电池行业则保守估计高达 250wh / kg。除非有重大技术突破，否则锂电池性能的改善将取决于材料优化。按此假设，到 2025 年，锂电池的电能密度预计可以达到 320wh / kg。

与此同时，锂电池的成本迅速下降，从 2011 年的每千瓦时 3000 元以上下降到 2015 年的 1500 元 / 千瓦时。市场参与者预计，到 2020 年，锂电池价格可能会降到 1000 元 / 千瓦时以下。正极材料、负极材料、隔膜和电解质有机溶剂占电池成本的比例分别为 30%、10%、25% 及 15%。[2] 由于其他部件的成本难以压缩，电池价格主要由正极材料决定。

永磁同步电机（包括无刷直流电机）、交流异步电机和交流感应电机是主流电机类型，其中最常见的是永磁同步电机。本地电动车型的额定功率大多在 20kw 到 35kw 之间。比亚迪的插入式电动车秦的额定功率达 40kw，是当地车型中最高的。特斯拉 Model S 等跑车车型可以达到 100kw。全球领先的电动车电机功率密度在 3kw / kg 和 6kw / kg 之间 。[3]

2. 摘自 ‘Promoting Automotive Power Battery Industry Development Action Plan’, Ministry of Industry & Information Technology (MIIT), 2017 年 9 月
3&4. 上海预致汽车咨询研究

新能源汽车平台战略

电动汽车平台的发展取决于技术与成本。一般而言，有三种选择：1. 开发一个新的电动车平台；2. 合作开发新的平台；3. 改造现有的内燃机车平台。

采用改造现有的内燃机汽车平台可以更好地控制成本，但是在设计方面存在限制。电池组通常较重，需要特定的设计。由于内燃机汽车平台最初不是为了适应电池组而设计的，电池组空间有限，这导致电池容量较低，行驶里程缩短。

新电动车平台中的电池组可以安装在汽车地板上，以有更多的电池容量。这能够保证电池重量均匀分布在车轴上，重心也更低，内部乘客空间更大。但是，新平台的开发需要大量的投资。如果销售初期受到限制，汽车厂商需要一段时间才能实现收支平衡，从而拖累业绩。这就是为什么使用新型电动车平台生产的电动汽车价格普遍较高的原因。

为了降低成本，一些制造商合作共同开发和分享新的电动汽车平台。然而，一些整车制造商仍然自行开发新平台，如特斯拉、大众、通用汽车和梅赛德斯 - 奔驰。

电动汽车还是插入式电动车，技术是决定因素

与插入式电动车相比，国内政策倾向于推广纯电池电动车。《企业平均燃料消耗量与新能源汽车积分并行管理暂行办法 (征求意见稿)》规定，按照驾驶里程，电动车将获得 2-6 分 ; 不管行驶里程多少，插电式混合动力汽车只能得到 2 分 。[5]

这一政策差别有多重原因:

例如，中国的电动汽车平均行驶里程只有 150 公里 -200 公里，插电式混合动力汽车可以达到更远的距离 。[6] 但是，随着电动车锂电池能量密度快速增长和制造成本迅速下降，预计未来五年内，电动汽车的平均行驶里程能够达到 400 公里左右，与插电式混合动力汽车相当。

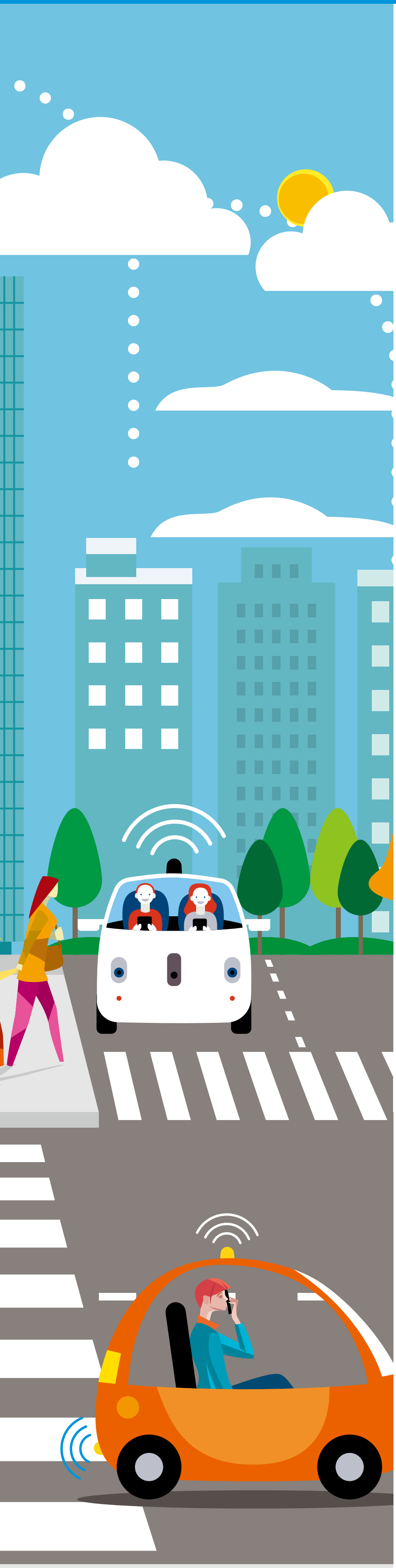
另一方面，插电式混合动力汽车的内在结构集成了从电动汽车和内燃机汽车继承的两套电力系统，这意味着插电式混合动力汽车价格昂贵，相对较重。插电式混合动力汽车的所有三个类型—并联混合动力汽车、串并联混合动力汽车和串联混合动力汽车。都有其自身的缺陷:

- 当混合动力汽车处于混合动力模式时，其燃料消耗高，而且电动机不能同时发电和驱动车轮。
- 串并联混合动力汽车有两个电动机，导致重量增加和相对复杂的控制系统。
- 在串联混合动力汽车中，发动机和发电机不直接驱动车轮，造成动力浪费。此外，重量没有明显下降，在高速路况下，油耗也很高。

当纯电动车和内燃机车续航里程相近，插电式混合动力汽车由于成本高，重量大，控制系统复杂，可能会失去其吸引力。相反，它们将会被视为纯电池电动汽车的过渡解决方案。

这与三年前的情况形成鲜明对比。彼时，大多数的整车制造商计划专注于插电式混合动力汽车，还没有制定电动车技术路线图。如今，情形已大不相同。现在很清楚，汽车制造商将积极发展电动车，而不是插电式混合动力汽车。例如，大众汽车宣布，到 2025 年，大众汽车生产的新能源汽车将主要是电动汽车 ; 丰田最近也决定重建已退役的电动汽车部门。

5. 工业和信息化部《企业平均燃料消耗量与新能源汽车积分并行管理暂行办法 (征求意见稿)》
6. 工业和信息化部《免征车辆购置税的新能源汽车车型目录》（第 1-12 批），2017 年



为自动驾驶设计的电动汽车

纯电动汽车比内燃机车型更适合自主驾驶。首先，自动驾驶汽车需要配置大量的传感器和先进的计算硬件和软件，因此会消耗更多的动力。内燃机车型使用 12V 电池供电的电气系统。与内燃机车型相比，配备高电压、高能量电池的电动汽车在自动驾驶硬件和软件方面，设计自由度更大。

其次，绝大多数纯电动汽车和插电式混合动力汽车电动汽车配备线控电子控制系统，此系统在结构上与自动驾驶兼容。线控电子控制系统的优点在于，电动汽车对加速 / 减速和制动命令的响应速度比内燃机模型快，另外，机械部件数量较少，可以减轻重量。而且，与结构复杂、容纳大约 2000 个部件的内燃机相比，纯电动汽车安装电动机和电池组简单得多。许多研发自动驾驶技术的公司，如通用、日产和谷歌，都选择了电动汽车作为自动驾驶原型的起始平台。

燃料电池作为替代

燃料电池汽车在中国普及率较低。日本和其他西方国家在这一领域仍然处于领先地位，这从中国氢能汽车补贴政策毫无进展便可以看出。

不过，政府已经开始更加关注燃料电池汽车。工业和信息化部关于汽车行业的战略报告显示，氢燃料电池汽车将被推广并准备进行大规模生产，力争到 2030 年有 10 万辆氢燃料电池汽车上路 。[7] 上海计划到 2020 年建设 5 到 10 个加氢站和 3000 辆燃料电池汽车上路 。[8]

由于燃料电池汽车成本高，燃料电池能否成功还有待观察。此外，燃料电池汽车需要建设足够的加氢站。业界普遍认为，大规模生产和推广需要 15 - 20 年以上的时间。国家对燃料电池汽车的关注度与日俱增，燃料电池汽车具有长途驾驶的优点，与电池电动汽车的市场定位不同，因此未来燃料电池汽车将于电池电动汽车实现共存。

7. 工业和信息化部《汽车产业中长期发展规划》，2017 年 4 月
8. 上海政府政策

» Conclusion
结语

The rapid decline of battery costs and growth in energy density meant by 2025-2030, the mileage and price of EVs will soon be able to satisfy consumer expectations. OEMs could soon replace PHEVs, while FCEVs have the potential to complement BEVs due to their long-distance capabilities.

Many manufacturers are developing new EV platforms to produce better designed vehicles that are lighter, safer and with a lower centre of gravity. While new platforms can lead to short-term cost increases, the jump in manufacturing costs should decline over time.

In addition, EVs are more compatible with automonous driving technologies. Future EV models are likely to be equipped with self-driving technologies, which will redefine the concept of driving. This could also promote car sharing, which could help to reduce traffic congestion.

电池成本快速下降和能源密度上升意味着， 2025 - 2030 年，电动汽车行驶里程和价格将很快能够满足消费者的期望。插电式混合动力汽车将很快被电池电动汽车所取代。燃料电池汽车因其长途驾驶性能，有可能成为纯电动汽车的补充。

许多厂商已经开始着手开发新的电动汽车平台，生产设计更优、重量更轻、更安全并且重心更低的电动汽车。虽然新的平台可能导致短期的成本增加，但成本的快速增加会随着时间慢慢减少。

此外，电动汽车与自动驾驶技术更加兼容。未来的电动车型很可能配备自动驾驶技术，这将彻底改变驾驶观念，促进汽车共享，并有助于降低交通拥堵。

» Contact us
联系方式

Huu-Hoi Tran
Partner, Advisory
Head of Automotive Sector
KPMG China
陈友合
汽车行业主管合伙人
毕马威中国
电话 Tel: +86 (10) 8508 5922
电邮 Email: huuhoi.tran@kpmg.com

Yale Zhang
Founder
AutoForesight
张豫
创始人
预致汽车咨询有限公司
电话 Tel：+86 (21) 3868 0868
电邮 Email：yz@autoforesight.com

刊物编号：CN-MS18-0001 Publication number: CN-MS18-0002
出版日期：二零一八年一月 Publication date: January 2018

Mainland China
中国内地

Beijing 北京
8th Floor, KPMG Tower, Oriental Plaza
1 East Chang An Avenue
Beijing 100738, China
中国北京东长安街1号
东方广场毕马威大楼8层
邮政编码：100738
Tel 电话 ：+86 (10) 8508 5000
Fax 传真 ：+86 (10) 8518 5111

Chongqing 重庆
Unit 1507, 15th Floor, Metropolitan Tower
68 Zourong Road
Chongqing 400010, China
中国重庆邹容路68号
大都会商厦15楼1507单元
邮政编码：400010
Tel 电话 ：+86 (23) 6383 6318
Fax 传真 ：+86 (23) 6383 6313

Fuzhou 福州
Unit 1203A, 12th Floor
Sino International Plaza,137 Wusi Road
Fuzhou 350003, China
中国福州五四路137号
信和广场12楼1203A单元
邮政编码: 350003
Tel 电话 ：+86 (591) 8833 1000
Fax 传真 ：+86 (591) 8833 1188

Hangzhou 杭州
12th Floor, Building A
Ping An Finance Centre, 280 Minxin Road
Hangzhou, 310016, China
中国杭州民心路280号
平安金融中心A幢12楼
邮政编码：310016
Tel 电话 ：+86 (571) 2803 8000
Fax 传真 ：+86 (571) 2803 8111

Qingdao 青岛
4th Floor, Inter Royal Building
15 Donghai West Road
Qingdao 266071, China
中国青岛东海西路15号
英德隆大厦4层
邮政编码：266071
Tel 电话 ：+86 (532) 8907 1688
Fax 传真 ：+86 (532) 8907 1689

Shenyang 沈阳
19th Floor, Tower A, Fortune Plaza
61 Beizhan Road
Shenyang 110013, China
中国沈阳北站路61号
财富中心A座19层
邮政编码：110013
Tel 电话 ：+86 (24) 3128 3888
Fax 传真 ：+86 (24) 3128 3899

Tianjin 天津
Unit 06, 40th Floor, Office Tower
Tianjin World Financial Center
2 Dagu North Road
Tianjin 300020, China
中国天津大沽北路2号
天津环球金融中心
津塔写字楼40层06单元
邮政编码：300020
Tel 电话 ：+86 (22) 2329 6238
Fax 传真 ：+86 (22) 2329 6233

Chengdu 成都
17th Floor, Office Tower 1, IFS
No. 1, Section 3 Hongxing Road
Chengdu, 610021, China
中国成都红星路3段1号
国际金融中心1号办公楼17楼
邮政编码：610021
Tel 电话 ：+86 (28) 8673 3888
Fax 传真 ：+86 (28) 8673 3838

Foshan 佛山
8th Floor, One AIA Financial Center
1 East Denghu Road
Foshan 528200, China
中国佛山灯湖东路1号
友邦金融中心一座8层
邮政编码：528200
Tel 电话 ：+86 (757) 8163 0163
Fax 传真 ：+86 (757) 8163 0168

Guangzhou 广州
21st Floor, CTF Finance Centre
6 Zhujiang East Road, Zhujiang New Town
Guangzhou 510623, China
中国广州市珠江新城珠江东路6号
周大福金融中心21楼
邮政编码：510623
Tel 电话 ：+86 (20) 3813 8000
Fax 传真 ：+86 (20) 3813 7000

Nanjing 南京
46th Floor, Zhujiang No.1 Plaza
1 Zhujiang Road
Nanjing 210008, China
中国南京珠江路1号
珠江1号大厦46楼
邮政编码：210008
Tel 电话 ：+86 (25) 8691 2888
Fax 传真 ：+86 (25) 8691 2828

Shanghai 上海
25th Floor, Tower II, Plaza 66
1266 Nanjing West Road
Shanghai 200040, China
中国上海南京西路1266号
恒隆广场2号楼25楼
邮政编码：200040
Tel 电话 ：+86 (21) 2212 2888
Fax 传真 ：+86 (21) 6288 1889

Shenzhen 深圳
9th Floor, China Resources Building
5001 Shennan East Road
Shenzhen 518001, China
中国深圳深南东路5001号
华润大厦9楼
邮政编码：518001
Tel 电话 ：+86 (755) 2547 1000
Fax 传真 ：+86 (755) 8266 8930

Xiamen 厦门
12th Floor, International Plaza
8 Lujiang Road
Xiamen 361001, China
中国厦门鹭江道8号
国际银行大厦12楼
邮政编码：361001
Tel 电话 ：+86 (592) 2150 888
Fax 传真 ：+86 (592) 2150 999

Hong Kong SAR and Macau SAR
香港特别行政区和澳门特别行政区

Hong Kong 香港
8th Floor, Prince's Building
10 Chater Road
Central, Hong Kong
香港中环遮打道10号
太子大厦8楼

23rd Floor, Hysan Place
500 Hennessy Road
Causeway Bay, Hong Kong
香港铜锣湾轩尼诗道500号
希慎广场23楼
Tel 电话 ：+852 2522 6022
Fax 传真 ：+852 2845 2588

Macau 澳门
24th Floor, B&C, Bank of China Building
Avenida Doutor Mario Soares
Macau
澳门苏亚利斯博士大马路
中国银行大厦24楼BC室
Tel 电话 ：+853 2878 1092
Fax 传真 ：+853 2878 1096

Ignition and Start-up Centres
创新空间

KPMG Digital Ignition Centre
毕马威智能创新空间
21st Floor, E07-1 Tower
Suning Intelligent City
272 Jiqingmen Street
Nanjing 210017, China
南京集庆门大街272号
苏宁慧谷E07-1号21楼
邮政编码：210017
Tel 电话 ：+86 (25) 6681 3000
Fax 传真 ：+86 (25) 6681 3001

KPMG Innovative Startup Centre
毕马威创新创业共享中心
Room 603, 6th Floor, Flat B
China Electronic Plaza
No. 3 Danling Street
Beijing 100080, China
中国北京丹棱街3号
中国电子大厦B座6层603室
邮政编码：100080
Tel 电话 ：+86 (10) 5875 2555
Fax 传真 ：+86 (10) 5875 2558

kpmg.com/cn